BBC

YURI GAGARIN: THE FIRST HUMAN IN SPACE

The cosmonaut's historic flight on its 60th anniversary

#191 APRIL 2021

Sky at Night

THE UK'S BEST SELLING ASTRONOMY MAGAZINE

Impossible STARS

The mysterious objects that throw the size of the Universe into doubt

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The kit that'll take your starscapes up a level – and it's not a camera

DARK SKIES ENGLAND

Discover the best places to go stargazing across the country

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Sky at Night ★★★★★ REVIEWED IN Issue 161 October 2018

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BBC SKY AT NIGHT MAGAZINE

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In short, the Esprit provided first-class optical performance visually and photographically…The Esprit-120's performance matches the best in the business at a competitive price"

SKYNEWS MAGAZINE REVIEW BY ALAN DYER

ESPRIT-150ED

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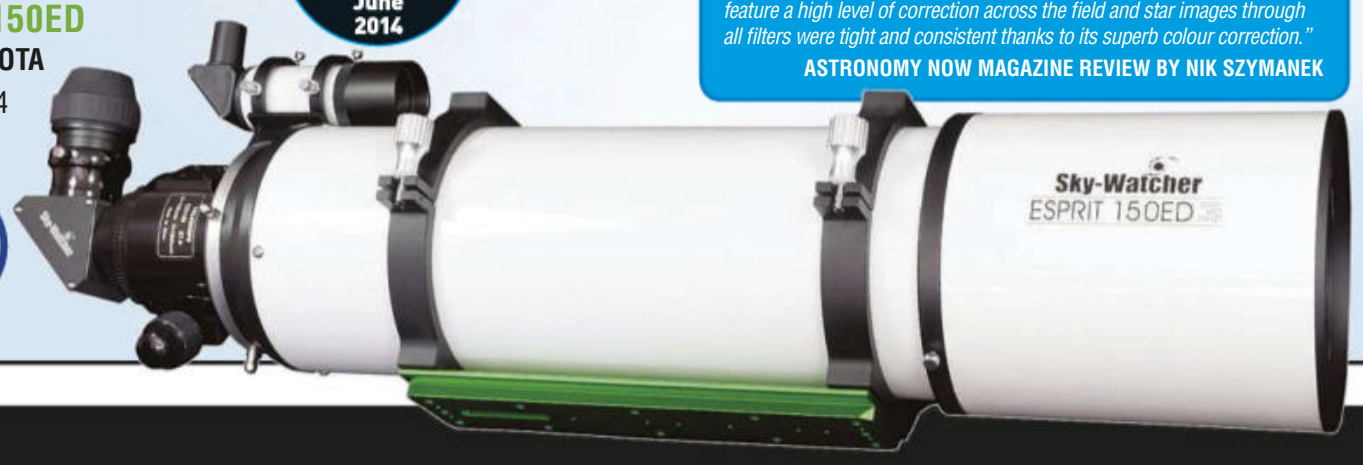
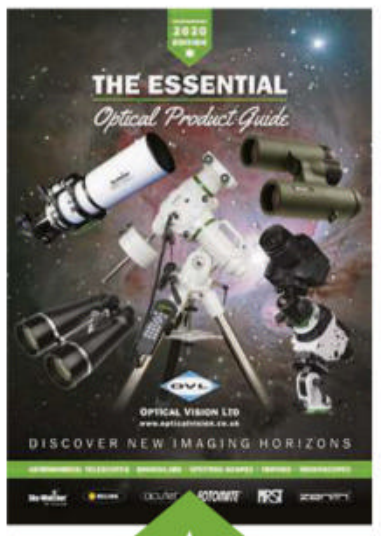
SRP £4999



"Star images were excellent across the full width of the sensor…The optics feature a high level of correction across the field and star images through all filters were tight and consistent thanks to its superb colour correction."

ASTRONOMY NOW MAGAZINE REVIEW BY NIK SZYMANEK



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Welcome

What can impossible stars tell us about cosmic distance?

In our interview on **page 94** this month with author and astronomer Neil deGrasse Tyson about his new book, there's a memorable line. "The greatest achievement in all of civilization is the awareness that the Universe is knowable," he says. I can certainly agree: that we understand so much about the vast reaches of space through the application of scientific principles is indeed a triumph.

Yet we should not fall into the trap of hubris: as Colin Stuart explains in his feature this issue, the foundation of this intergalactic knowledge – the 'ruler' astronomers use to survey the unimaginable distances of space and time – is shakier than we might realise. Turn to **page 30** to discover the impossible stars that may be the broken rung in this 'cosmic distance ladder', and the latest attempts by astronomers to get to the bottom of this cosmological mystery.

There is, however, one achievement that we're proud to celebrate this month as we mark its 60th anniversary, that is Yuri Gagarin's flight to space on 12 April 1961, to become the first human to leave Earth's atmosphere and reach orbit. On **page 60**, Elizabeth Pearson uncovers the backstory to Gagarin's mission – much of which was kept classified for decades – and the cosmonaut's triumphant unofficial visit to the UK.

Staying close to home, on **page 66** Jamie Carter looks at England's best stargazing locations. The areas he covers all have guaranteed dark skies; many are internationally recognised, while some are less well known but equally worth a visit when regulations ease and we can once again take in the wonder of the night sky free from light glow.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 22 April.

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Editorial enquiries
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9:30am–5.30pm, Mon–Fri

Advertising enquiries
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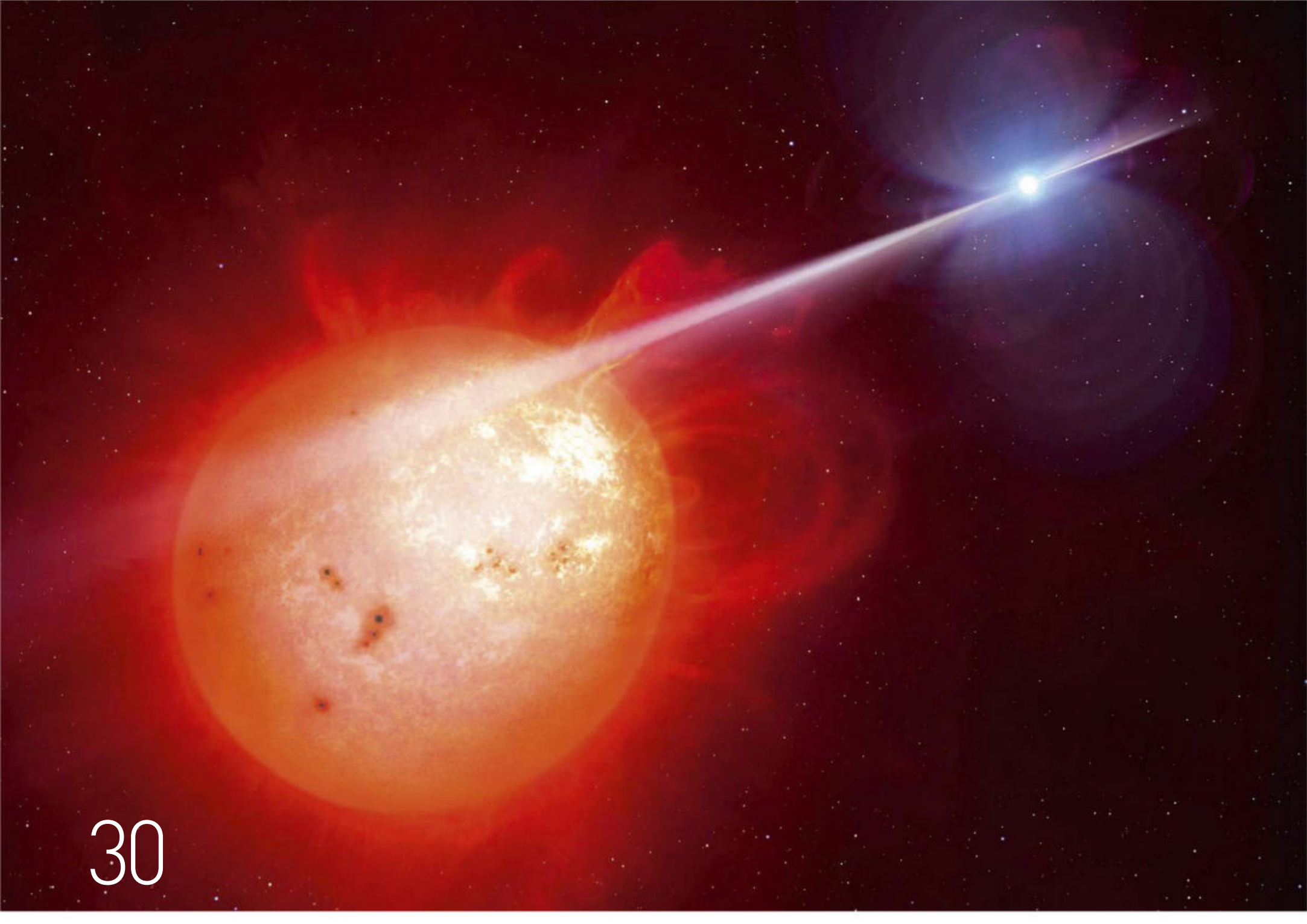

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COVER MAIN IMAGE: CAPPAN/ISTOCK/GETTY IMAGES. THIS PAGE: MARK GARLICK/SCIENCE PHOTO LIBRARY/ISTOCK/GETTY IMAGES, WILL GATER, @THESHED_PHOTOSTUDIO, SPUTNIK/ALAMY STOCK PHOTO, MATT_GIBSON/ISTOCK/GETTY IMAGES, BETH BILLER

New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**

This month's contributors

Ezzy Pearson

News editor

"Yuri Gagarin's flight was one of the greatest moments in spaceflight, but it's long been hidden behind a veil of secrecy. It was fascinating to get to the real story". **Ezzy on the first human spaceflight, 60 years ago,** page 60

Colin Stuart

Astronomy author

"I've always been in awe of how astronomers can measure distances in space, but this article interested me because it appears things may not be as straightforward as they seem." **Colin explores impossible stars,** page 30

Jenny Winder

Author and journalist

"Media hype over supermoons has always irritated me. I think it elevates the public's expectations, so I wanted to put the record straight." **Jenny separates supermoon fact from fiction,** page 72

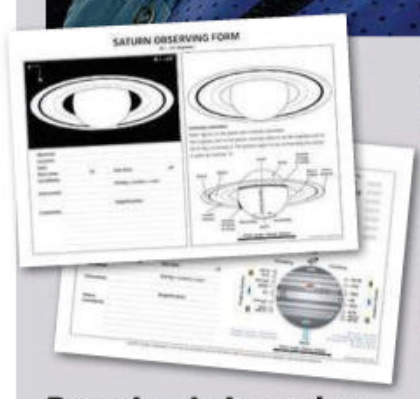
Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/CBMUG3U/** to access this month's selection of exclusive Bonus Content

APRIL HIGHLIGHTS

Interview: imaging exoplanets

Astronomer Beth Biller discusses the instrument she'll use to photograph planets around distant stars.



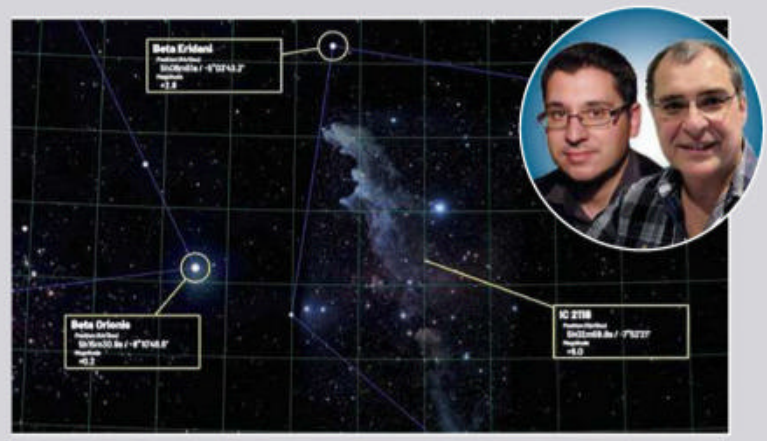
Download observing guides and charts

Access planet observing forms, binocular and deep-sky tours and our guide to Southern Hemisphere stargazing.

Audiobook preview: *Helgoland*

Download and listen to an extract from physicist Carlo Rovelli's new book about Heisenberg's quantum revolution.

The Virtual Planetarium



Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

NEW ARRIVALS ON MARS

The UAE's image marks the start of a new era, as three missions begin to explore the Red Planet

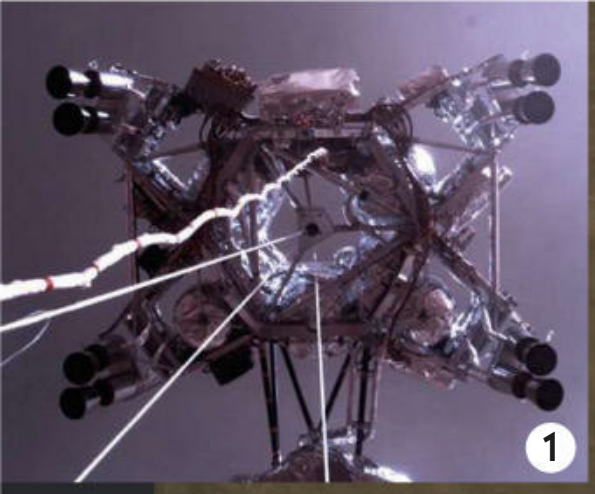
HOPE PROBE, 10 FEBRUARY 2021

Three Mars-bound spacecraft set off within days of each other in February – the Emirates Mars Mission, China's Tianwen-1 and NASA's Mars 2020 – but it was the UAE (United Arab Emirates) that first successfully entered the Red Planet's orbit, returning this moody shot encapsulating the mysteries waiting to be unwrapped by all three.

The new kids on the planetary spaceflight block, the Emirates took just six years from initial feasibility studies to sending up their atmospheric probe Hope (Al-Amal), the first step in their ambitious 100-year plan, announced in 2017, to ultimately build a city on Mars.

Hot on Hope's heels was China's Tianwen-1, which arrived in Martian orbit on the same day that this image was taken, although it will be May before the Chinese attempt to land their rover on the Red Planet's surface.

UAESA/MBRSC/LASP/EMM-EXI



◁ Falling with style

MARS PERSEVERANCE, 18 FEBRUARY 2021

NASA's Perseverance was the second of the three missions to recently arrive at Mars. As well as seven primary payload instruments, two microphones and a mini-helicopter, it has 19 cameras on board which captured the first ever video of a spacecraft landing on a planet.

These stills show the powered descent to the ground. Having cut itself free of its vast 21m-diameter parachute, in a swift 20-second manoeuvre starting just 20m above the surface, a sky crane (1) lowered the rover before the cables were severed (2) and the descent stage flew off to crash-land 700m away (3).

▽ Make Mars your own

MARS PERSEVERANCE, 21 FEBRUARY 2021

One of the first new images of the Martian surface, imaged by Perseverance's Hazard Avoidance Cameras (Hazcams) and processed by astrophotographer and science writer Will Gater. Will says: "I created the full colour image by combining three separate red, green and blue colour channels taken by the rear right Hazcam on Sol 2. The colour is my interpretation of what the colour would be. I've tried to remove the lens distortion from the Hazcam and added in sky where that process left a gap."

NASA is making Perseverance's raw data publicly available for anyone to download and process at **mars.nasa.gov/mars2020/multimedia/raw-images**

MORE **ONLINE**

A gallery of these and more stunning space images

◁ Glowing serpent

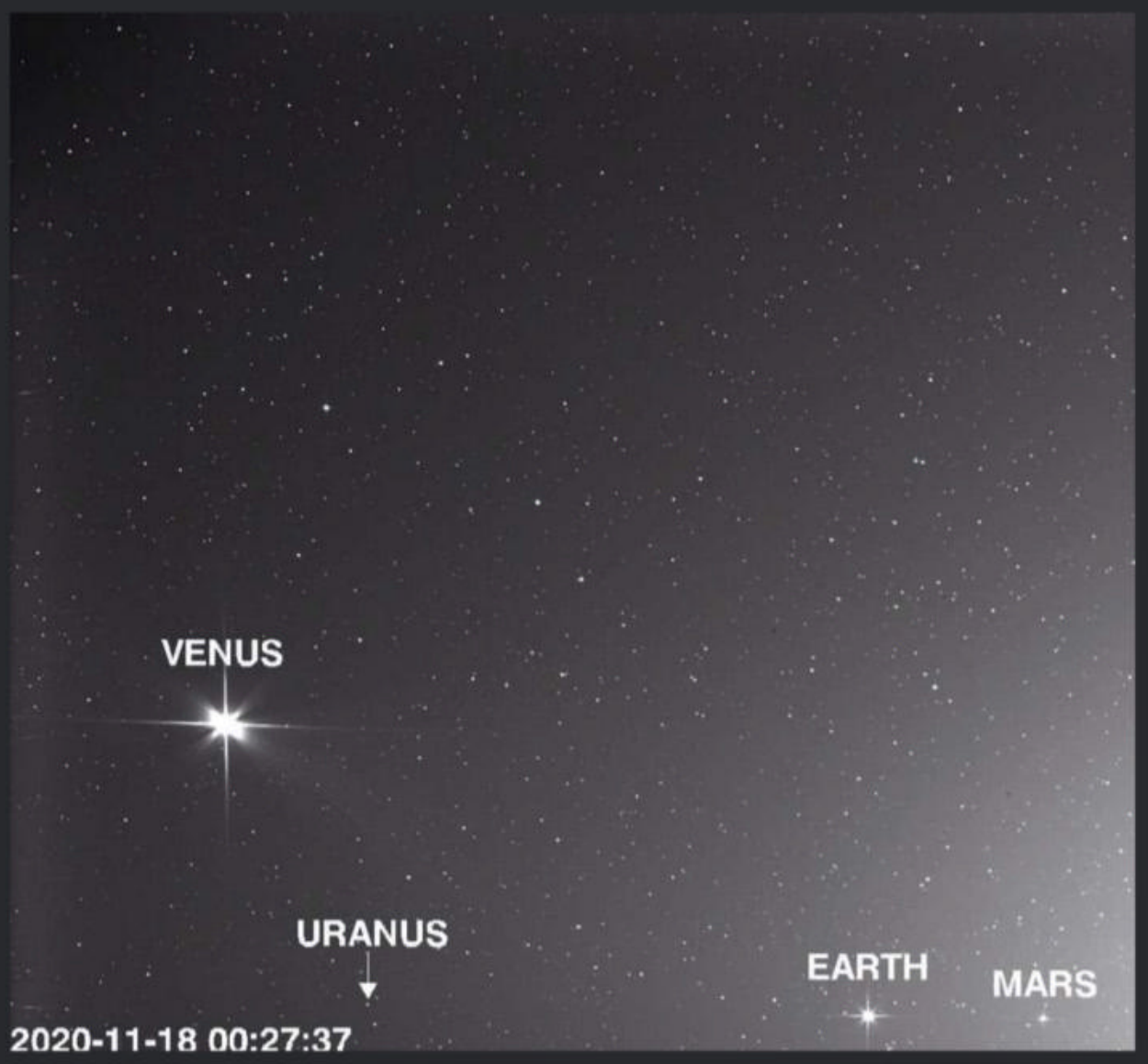
CERRO TOLOLO INTER-AMERICAN OBSERVATORY, 27 JANUARY 2021

An unfamiliar target within a much wider nebulosity that includes the more famous Eagle and Omega Nebulae, emission nebula Sh2-54 in Serpens is imaged here in incredible detail and three different wavelengths by the SMARTS 0.9m Telescope at Cerro Tololo Inter-American Observatory in Chile. The intensely glowing core is thought to house a multitude of young high-mass stars.

New perspective on the planets ▷

SOLAR ORBITER, 18 NOVEMBER 2020

Here's a view you don't see every day. This image shows Venus, Uranus, Earth and Mars as seen by the Heliospheric Imager (SoloHI) on NASA's Solar Orbiter as it looked back towards home from its unique perspective, 250.6 million kilometres out in space. Although primarily tasked with observing our central star, the craft's side-looking camera saw several planets pass through its field of view in recent months.



NASA/JPL-CALTECH X 3, NASA/JPL-CALTECH/WILL GATER, CTIO/NOIRLAB/NSF/AURA, ESA/NASA/NRL/SOLAR ORBITER/SOLOHI

◁ Unseen powerhouse

HUBBLE SPACE TELESCOPE, 15 FEBRUARY 2021

Herbig–Haro objects, bright, multi-coloured jets of matter first observed in the 19th century, evaded explanation for decades until these two examples unlocked the solution. HH46 and HH47, discovered in 1977 by US astronomer RD Schwartz, were found to be shooting out from a protostar, not visible in this image – a newly-born star from which material is being violently ejected at 150km/s.

▽ A beautiful black eye

HUBBLE SPACE TELESCOPE, 22 FEBRUARY 2021

NGC 4826 may be dubbed the Black Eye Galaxy because of the dark sweep of dust that swathes half of its bright core, but it could also earn the nickname for another reason: a violent blow from another galaxy. Found 17 million lightyears away in the constellation of Coma Berenices, the gas in the outer regions of this spiral rotates in the opposite direction from that in its inner regions. This eccentric gyration may be from a long-past collision with a satellite galaxy.

ESA/HUBBLE & NASA/B. NISINI, ESA/HUBBLE & NASA/J. LEE AND THE PHANGS-HST TEAM

BBC Sky at Night MAGAZINE

VIRTUAL LECTURE

My lockdown project: learning astrophotography

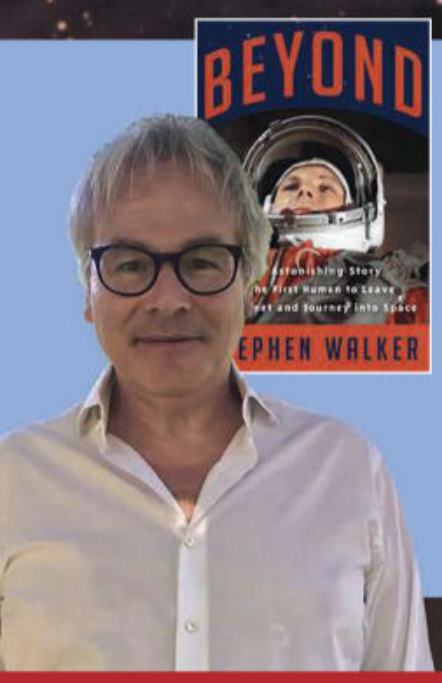
With Dara Ó Briain

Somewhere in this past year of lockdowns, comedian Dara Ó Briain decided to capture the cosmos for himself, attached a camera to his telescope and began photographing the night sky.

Join the host of *Mock the Week*, *Stargazing Live*, *Dara Ó Briain's Science Club* and *Blockbusters* as he talks about his new hobby to *BBC Sky at Night Magazine* editor Chris Bramley, and shares his experiences of being a beginner at the start of the steep astrophotography learning curve.

They'll take a light-hearted look at some of the frustrations that come with taking pictures in the dark, top tips for how not make your telescope an instant health hazard and getting to grips with image-processing, and those occasional times when faint photons of starlight stay in focus and make it into a finished photo.

When: Thursday 25 March 2021, 7pm GMT
Where: Live on Big Marker
Tickets: £10 per person



Also coming up:

Yuri Gagarin – The Untold Story of the First Human in Space, with Stephen Walker

Join Stephen Walker, documentary director and author of *Beyond*, an exhilarating new book about Yuri Gagarin's historic flight to Earth orbit, as he tells the gripping tale of the race between the superpowers to put the first person in space on its 60th anniversary.

When: Friday 23 April 2021, 7pm GMT • Where: Live on Big Marker • Tickets: £10 per person

Book your tickets today at:
www.skyatnightmagazine.com/virtual-lecture

This was Sylvia's promise to you...

A generation ago, a woman named Sylvia made a promise. As a doctor's secretary, she'd watched stroke destroy the lives of so many people. She was determined to make sure we could all live in a world where we're far less likely to lose our lives to stroke.

She kept her promise, and a gift to the Stroke Association was included in her Will. Sylvia's gift helped fund the work that made sure many more of us survive stroke now than did in her lifetime.

Sylvia changed the story for us all. Now it's our turn to change the story for those who'll come after us.

Stroke still shatters lives and tears families apart. And for so many survivors the road to recovery is still long and desperately lonely. If you or someone you love has been affected by stroke – you'll know just what that means.

But it doesn't have to be like this. You can change the story, just like Sylvia did, with a gift in your Will. All it takes is a promise.

You can promise future generations a world where researchers discover new treatments and surgeries and every single stroke survivor has the best care, rehabilitation and support network possible, to help them rebuild their lives.

Big or small, every legacy gift left to the Stroke Association will make a difference to stroke survivors and their families.

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or email legacy@stroke.org.uk

or visit stroke.org.uk/legacy

Rebuilding lives after stroke

Stroke Association

BULLETIN

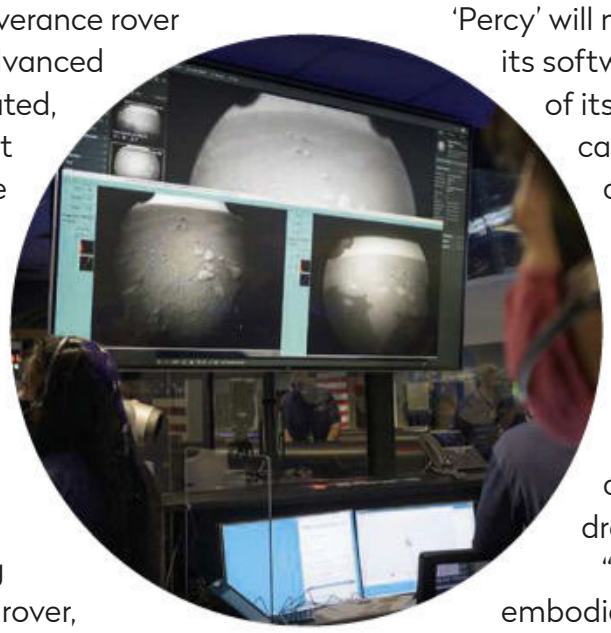
Perseverance lands on Mars

The rover will collect rocks that will one day be returned to Earth

At 20:55pm UT on 18 February NASA's Perseverance rover landed on Mars. As well as being the most advanced robotic geologist and astrobiologist ever created, it marks the first stage of one of NASA's most ambitious plans ever. Perseverance will create caches of Mars rock that a future mission, currently being planned by both NASA and the European Space Agency (ESA), will collect and return to Earth.

"What they could tell us is monumental – including that life might have once existed beyond Earth," says Thomas Zurbuchen, associate administrator for science at NASA.

The rover used the same sky crane landing system that was developed for the Curiosity rover, touching down just north of Mars's equator in the Jezero crater. The region is home to an ancient river delta and it's believed the crater was filled with water 3.5 billion years in the past, meaning it could have once hosted life.

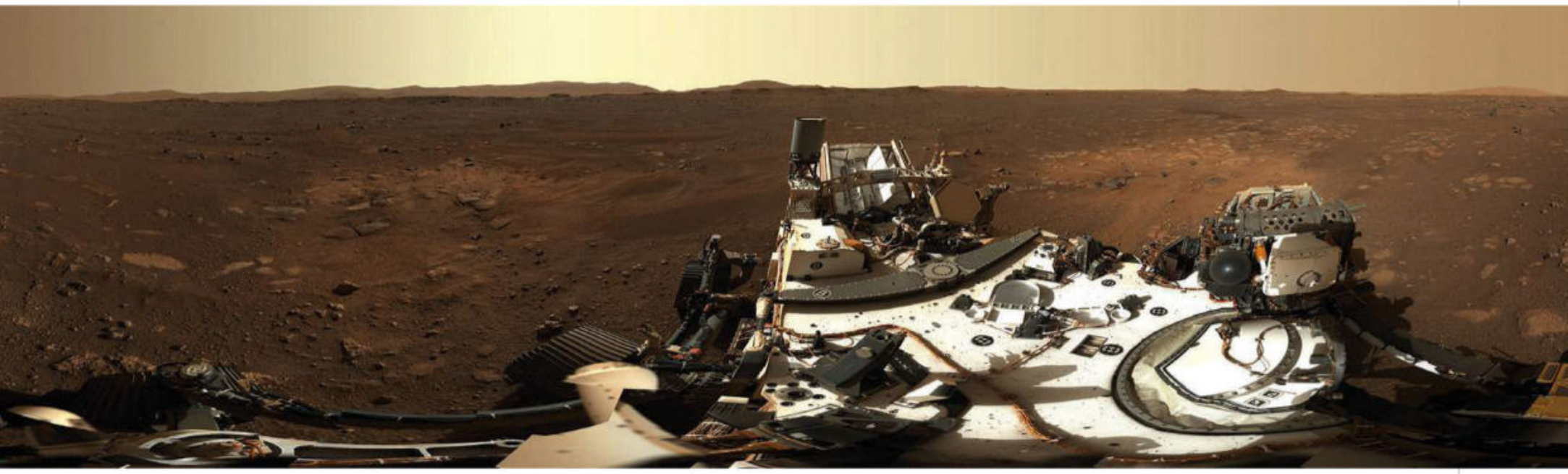


▲ **First look: the Perseverance rover sends back images of Mars**

'Percy' will now spend the next few weeks updating its software and undergoing engineering tests of its instruments, robotic arm and driving capabilities. One of the first items to be checked was the Ingenuity Mars Helicopter, a prototype drone-like spacecraft that will fly through Mars's thin atmosphere to traverse large distances over difficult terrain that wheeled rovers can't cross. The probe appears to be in working order and will spend the next few weeks charging up its batteries, before being dropped onto the surface this spring.

"The Mars 2020 Perseverance mission embodies our nation's spirit of persevering even in the most challenging of situations, inspiring and advancing science and exploration," says NASA's acting administrator Steve Jurczyk.

www.nasa.gov



▲ **Panorama: a stunning view of the Martian landscape taken by the Mastcam-Z, a pair of zoomable cameras onboard Perseverance**

NASA/BILL INGALLS, NASA/JPL-CALTECH/ASU/MSSS

Comment

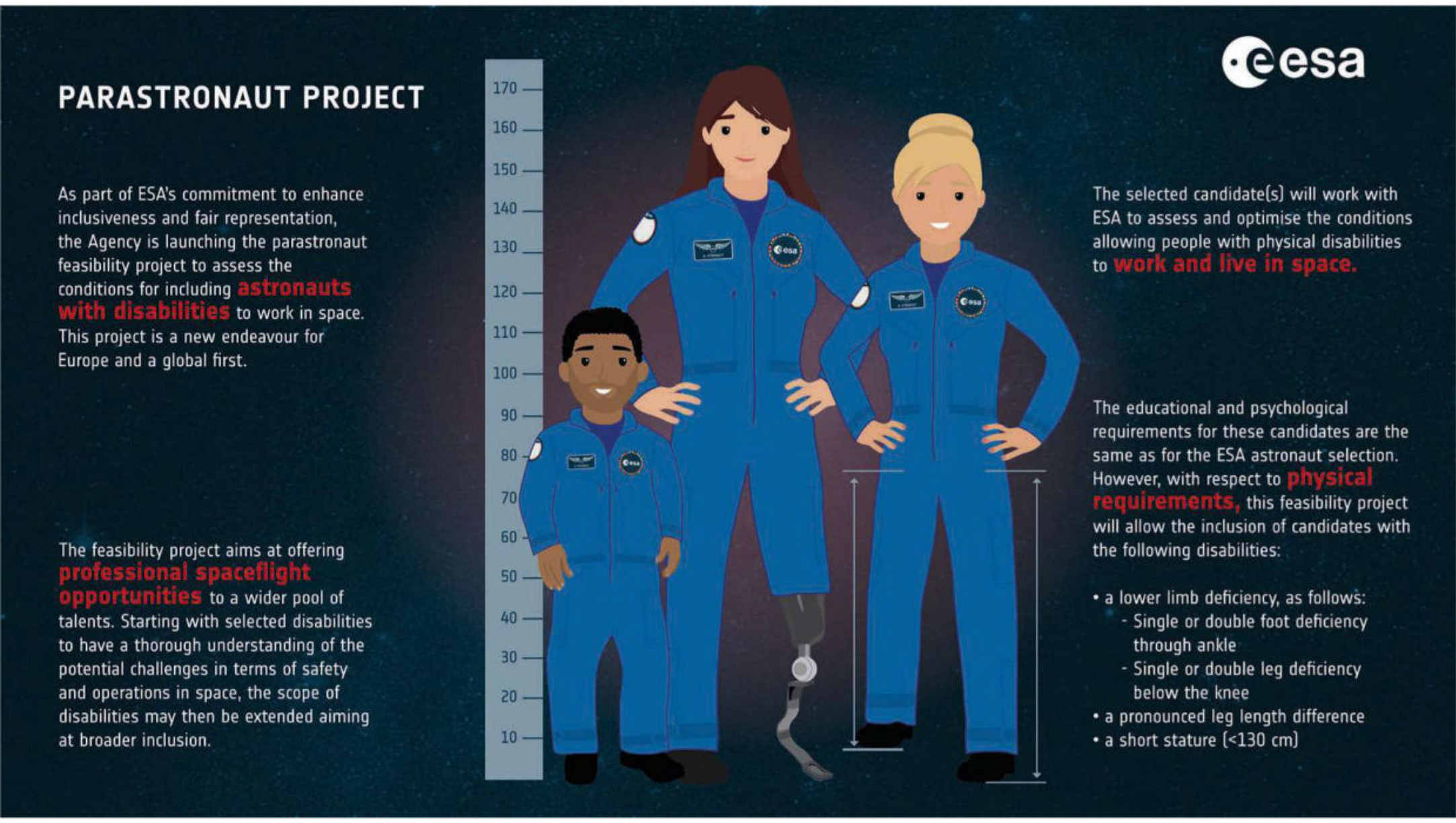
by Chris Lintott

Until it arrived at Jezero crater, I hadn't paid too much attention to Perseverance. Even if all goes well on this mission, successful sample return is a decade and several missions away, and – Ingenuity aside – it seemed close to a copy of Curiosity rather than a scientific upgrade.

I'm excited now, though! The glorious video of its ride to the Martian surface has been a worldwide smash hit, and it's impossible not to thrill at the sight of the rover touching down and the view of the receding sky crane.

The landscape is equally thrilling; thanks to more intelligent systems giving much more control on landing, we've ended up in the most interesting place yet visited on Mars. As images arrive, the vista of a river delta is opening up, and I can't wait for the rover to spin its wheels and go roving.

Chris Lintott co-presents *The Sky at Night*



▲ **Pioneering parastronauts: the European Space Agency is reaching out to applicants with physical disabilities for the first time**

Space needs you!

Dust off the CV – ESA has issued a rare call for astronaut applications

It's time to brush up on the CV and get ready for launch as the European Space Agency (ESA) is looking for new astronauts for the first time since 2008.

The agency is keen to ensure they are accessible to all so in this call, as well as people of all genders, sexual identities and ethnicities, ESA is also looking for people with lower limb deficiencies, pronounced leg differences or short stature to apply to take part in its parastronaut feasibility project. These candidates will help assess if and how space could be made accessible to those with physical disabilities.

"We feel we have a responsibility to at least try and make this happen and lead by example," says David Parker, ESA's director of human and robotic exploration. "We hope to push the envelope of disability at work and inspire people with special needs to apply to other roles within ESA and other areas of the space industry."

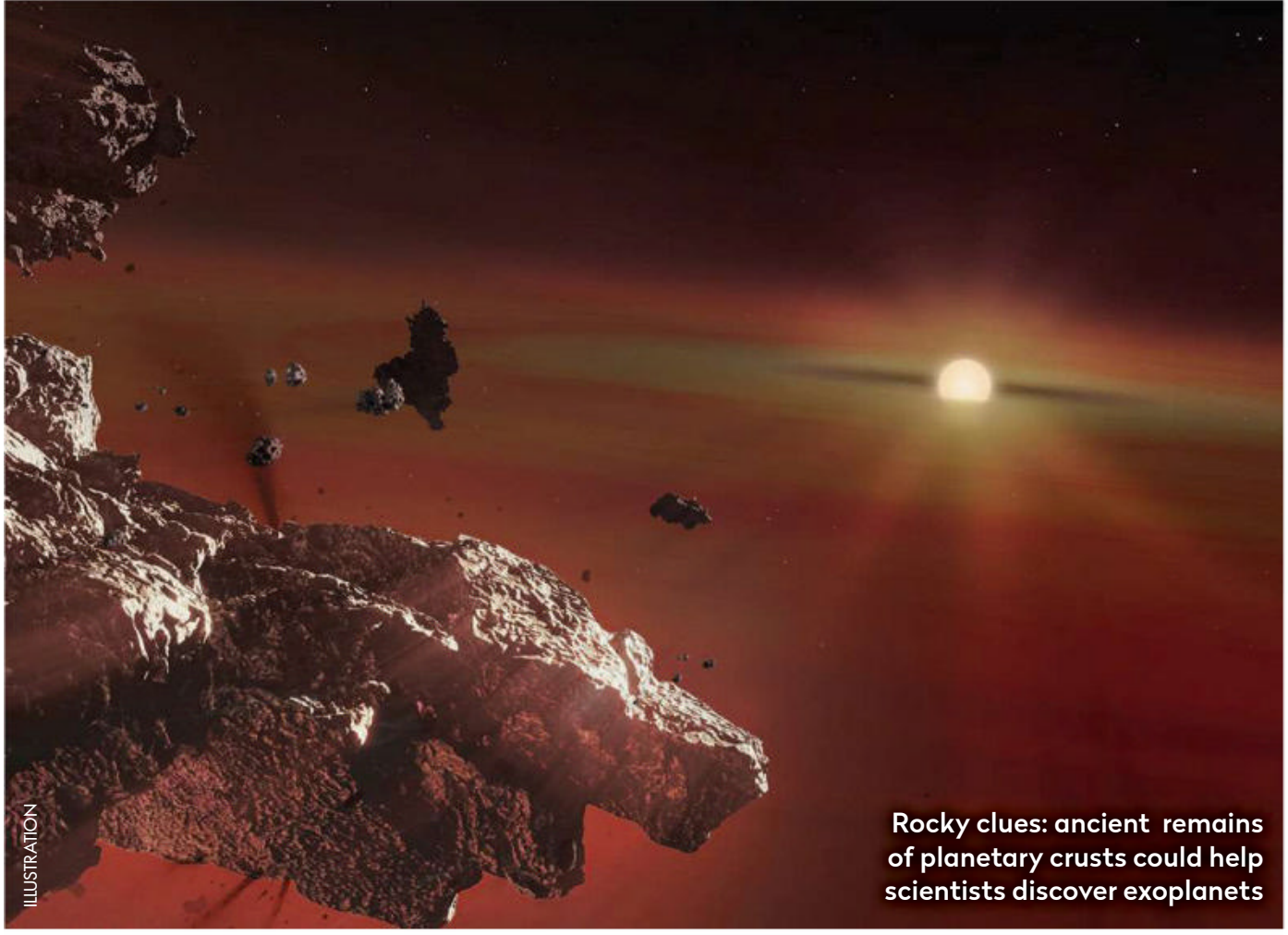
Potential parastronauts will need to meet the same exacting set of requirements as the candidates for the main corps. Applicants will need to have either at least a master's degree in a natural science, maths, engineering or medicine with at least three years postgraduate experience, or be a qualified test pilot. They'll also need to be a citizen of an ESA member state (which includes the UK) or associate state, be fluent in English with good knowledge of a second language, have good communications skills, be able to remain calm under pressure and be a quick decision maker. Finally, they will need a certificate from an aviation medical practitioner (find out how to obtain one at **www.caa.co.uk**). Applications are open from 31 March to 28 May 2021.

As this class of ESA astronauts could one day be assigned to a lunar mission, competition is expected to be even more fierce than it was last time, when 8,413 people applied for just six places. But British astronaut Tim Peake encourages potential candidates not to be discouraged.

"It's a long journey, but it's an incredibly exciting one," says Peake. "It's a life-changing one and I am really excited for anybody who is applying to this new selection process. Some of the future missions these astronauts have to look forward to are quite incredible."

www.esa.int/About_Us/Careers_at_ESA

ESA, UNIVERSITY OF WARWICK/MARK GARLICK, NASA/ESA AND T. BROWN AND S. CASERTANO (STSCI), NOIRLAB/NSF/AURA/J. DA SILVA



ILLUSTRATION

Rocky clues: ancient remains of planetary crusts could help scientists discover exoplanets

Planetary remnants found in dying stars

The find could provide a new way to hunt for rocky exoplanets

The remains of planets with Earth-like crusts have been seen floating through the atmospheres of four white dwarfs. Data from ESA's Gaia satellite showed the signatures of lithium and potassium in the same ratio found in the crusts of planets like Mars and Earth, a presence that suggests the crusts of rocky planets were vaporised and mixed with the stars' atmospheres at least two million years ago.

"In the past we're seen all sorts of things like mantle and core material, but we've not had a definitive detection of planetary crust," says Mark Hollands from the University of Warwick, who led the study. "Now we know what chemical signature to look for to detect these elements, we have the opportunity to look at a huge number of white dwarfs and find more of these."

If astronomers could detect such signs, it would be a way to look for rocky exoplanets that can't be found with traditional surveys.

www.cosmos.esa.int/web/gaia

Black holes collect in clusters

Located just 7,800 lightyears from Earth, NGC 6397 is a particularly densely packed collection of stars. Hoping such a cluster might be home to the 'missing link' of black hole evolution, an intermediate black hole, astronomers measured the distribution of mass in the cluster by looking at the motions of stars within it using data taken from the Hubble Space Telescope and ESA's Gaia observatory.

"We found strong evidence for invisible mass in the dense central regions of the cluster, and we were surprised to find that this extra mass is not point-like but extended to a few per cent of the size of the cluster," says Eduardo Vitral from the Institut d'Astrophysique de Paris, who led the study.

It appears that the cluster houses not one intermediate black hole, but many stellar-sized ones. The astronomers suggest that such closely packed black holes could easily merge together, offering a potential mechanism for black holes to grow.

www.hubblesite.org

▲ **Core values: the Hubble Space Telescope has uncovered a concentration of small black holes in the globular cluster NGC 6397**

NEWS IN BRIEF


ILLUSTRATION

Most distant space rock confirmed

Farfarout is now officially the Solar System's most distant known object – at least for now. Astronomers recently confirmed the orbit of the planetoid, discovered in 2018, finding it is currently 132 times the Earth–Sun distance from the Sun. There are other objects such as Sedna, which have orbits that will travel further away in the future, however.

Fireball over UK

A bright 'fireball' meteor – one brighter than the planet Venus – was seen across the UK from Scotland to Somerset on 28 February 2021, at around 21:45 UT. Unusually, many people reported hearing a rumbling boom along with the slow-moving bright light in the sky.

UK and Australia sign space deal

The UK and Australia have signed a new 'Space Bridge' partnership, to aid exchanges of knowledge and investment between the two countries' space sectors. The deal aims to help both nations achieve their goals of being globally competitive space powers.

NEWS IN BRIEF

Case closed on dino death

It's official – a dinosaur-killing asteroid hit the Earth 66 million years ago. Asteroid dust has been found in the Chicxulub impact crater, in the rock layer dating from the time of the great extinction, definitively linking the two together.

A bevy of binaries

Binary stars are all around us, as shown by the latest star data from the Gaia space observatory. Astronomers searched the catalogue for widely separated binary stars, finding 1.3 million within 3,000 lightyears of Earth – previously only around 200 were known.

Earth life survives on Mars

Earth microbes could temporarily survive on the surface of Mars. Several micro-organisms on a weather balloon survived a trip to the stratosphere – where the atmospheric conditions are similar to Mars, suggesting future Martian explorers might be able to cultivate the organisms needed to keep humans and crops healthy.

ESTI/ ISTOCK/GETTY IMAGES, DOTTEDHIPPO/ISTOCK/GETTY IMAGES, CALTECH/R. HURT (IPAC), ANDREW KLINGER

BULLETIN

Origin of super-Earths uncovered

Rather than once being gas planets, the worlds could form on their own

ILLUSTRATION

A rocky start: scientists have shed new light on the origins of super-Earths

Super-Earths could have a rocky childhood. A new study has shown that these planets, which are up to four times Earth's size, could form as rocky worlds rather than being what's left after a gaseous mini-Neptune loses its atmosphere.

Super-Earths and mini-Neptunes are the most common types of known exoplanets, with around 30 to 50 per cent of all stars hosting one or the other. To understand their role in creating planetary systems, a team of astronomers simulated how such planets might grow.

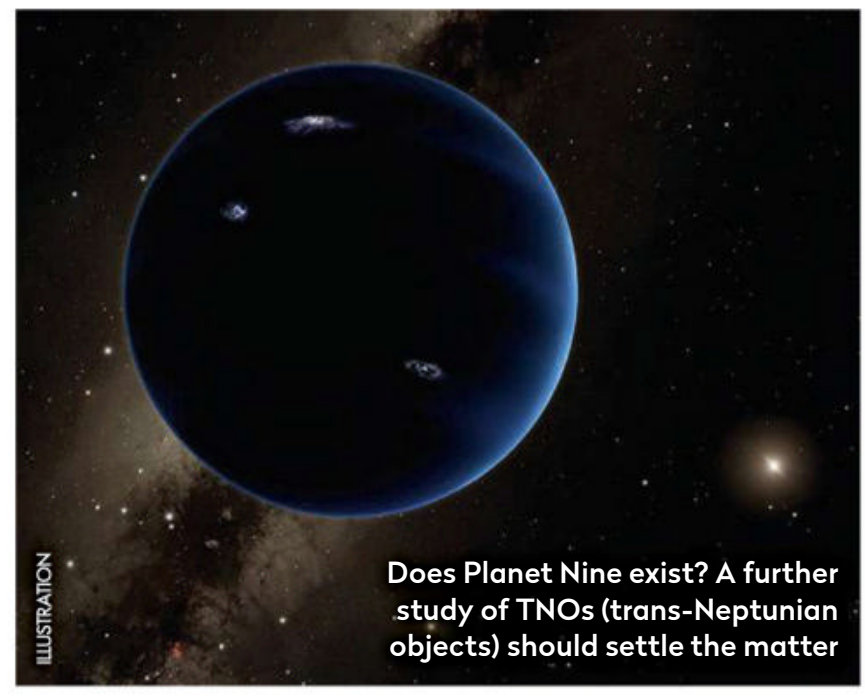
"Some of the rocks grew gas shells, while others emerged and remained rocky super-Earths," says Eve Lee, from McGill University, who took part in the study. "Our findings help explain the origin of the two populations of exoplanets, and perhaps their prevalence.

"We could eventually decipher how common rocky exoplanets like Earths and mini-Earths may be."

www.mcgill.ca

Existence of Planet Nine in question

Doubts are beginning to deepen around the existence of Planet Nine. The hypothetical planet beyond Neptune was first suggested in 2016, when astronomers noticed a cluster of trans-Neptunian objects (TNOs) – space rocks in the outer Solar System – that seem to have been shepherded into place by a distant planet. A new report, however, suggests this apparent clustering is actually just where the telescopes are most sensitive after they created a map to show where TNOs are most likely to be found. A more unbiased survey could reveal the 'cluster' is just part of a more uniform distribution.



ILLUSTRATION

Does Planet Nine exist? A further study of TNOs (trans-Neptunian objects) should settle the matter

Whether Planet Nine exists or not is a controversial topic among astronomers. TNOs are so small and dim, we only know of a handful. This makes testing theories about whether they are or aren't affected by a ninth planet very difficult. Fortunately, the upcoming Vera C Rubin Observatory, due to become fully operational in 2023, will be able to detect hundreds of new TNOs, and is expected to put the question to rest once and for all.

www.lsst.org

How hot is a red supergiant?

Red supergiant stars are due to get their temperature taken, as astronomers have developed a new way to measure how hot they are.

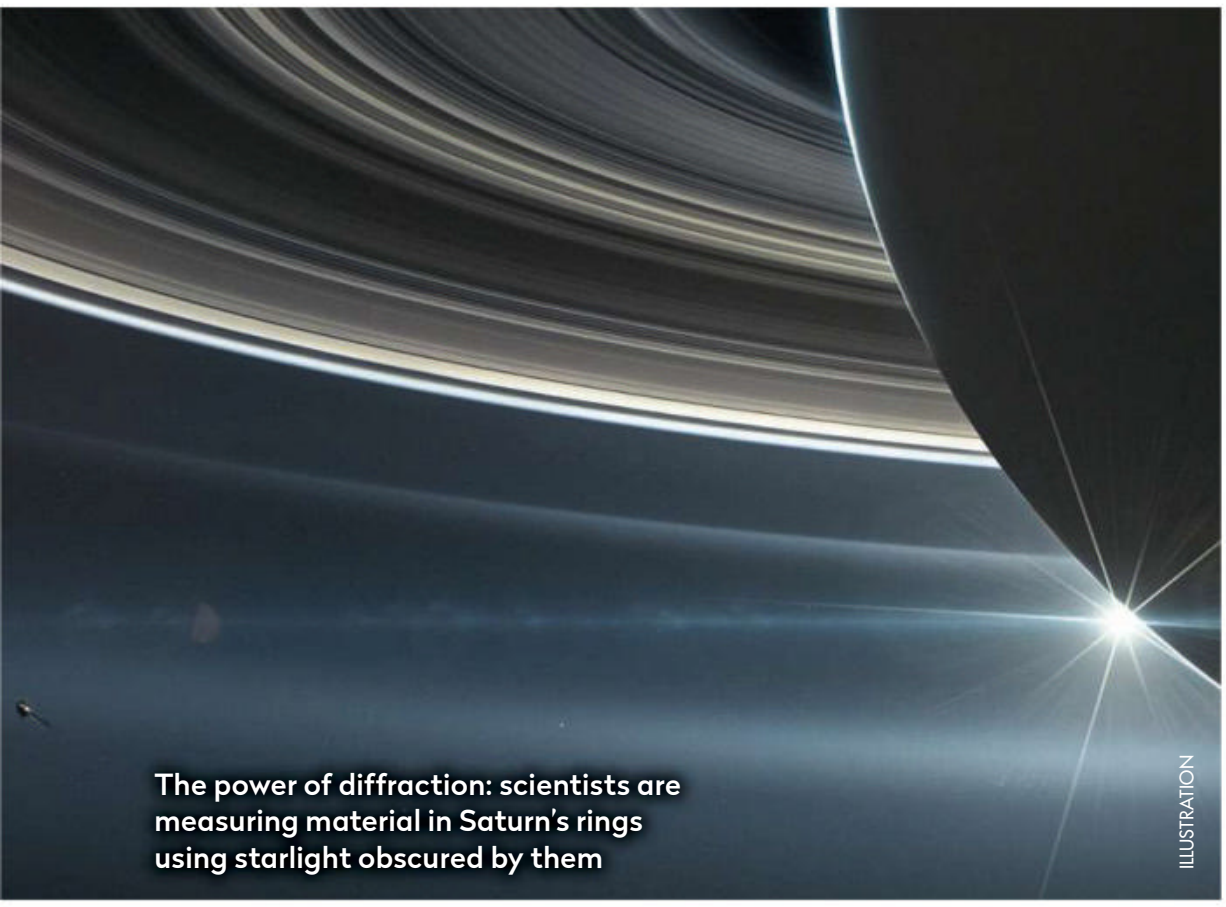
These huge stars, like Betelgeuse (pictured), are at least nine times the mass of the Sun and end their lives in huge Type II supernovae. But it's difficult to predict when these explosions will occur as their upper atmospheres make it difficult to measure their temperatures.

Astronomers from the University of Tokyo solved the problem, however, by measuring two of the spectral lines created by iron atoms in the stars, using the ratio to gauge their temperature.

"I think this research will help astronomers fill in some of the blanks," says Daisuke Taniguchi, who led the research. "Betelgeuse could go supernova in our lifetimes. It would be fascinating if we were able to predict if and when it might happen."

Our experts examine the hottest new research

CUTTING EDGE



The power of diffraction: scientists are measuring material in Saturn's rings using starlight obscured by them

ILLUSTRATION

Measuring Saturn's twinkling rings

The light diffracting through the particles of Saturn's rings helps astronomers measure their size

Diffraction is more often than not the bane of any observational astronomer's life. This wave property of light means that light entering the aperture of a telescope spreads out slightly – just like water waves passing through the opening in a harbour wall. For an astronomer, diffraction acts to limit the maximum resolution that can be achieved with a telescope, and a point source like a star appears surrounded by a series of rings.

Exactly the same phenomenon also occurs when light waves pass and interact with a small particle. And it turns out that this effect can be exploited to do some very nifty astronomical science. Stephanie Eckert, at the Department of Physics, University of Central Florida, and her colleagues have been doing just that to explore the ring system of Saturn.

Saturn's rings are composed of particles of water ice and are far from uniform: they're a complex system of multiple rings and smaller ringlets of slightly different shades, many with clearly defined edges, and also with some conspicuous gaps. The outermost of the large, bright rings – the A ring – for example, has its inner boundary at the Cassini Division, a sharp outer edge close to the orbit of the small moon Atlas, and also contains the broad Encke Gap that has been cleared out by the small moon Pan.

Matters of size

The small ice particles present in the rings diffract light passing them. If you observe a star behind Saturn and record it flickering in and out as it's obscured by the individual rings, you can measure the spikes in brightness caused by the icy particles near the ring edge diffracting light into your detector. The size and abundance of the smallest particles determines the strength of this signal, so you can use it to measure the distribution of particles near the ring edges. Planetary scientists have tried this trick in the past, and now Eckert and her colleagues have analysed data from the Cassini spacecraft's Ultraviolet Imaging Spectrograph (UVIS) for 275 occasions where Saturn's ring system occulted a star.

"Eckert and her team observed an overall decrease in diffraction signatures from Saturn's outer rings towards the planet"

Eckert and her team observed an overall decrease in diffraction signatures from the outer rings towards the planet, confirming earlier reports that the minimum particle size gets bigger and bigger towards the planet. They determined that the minimum size of icy particles along the outer edge of the A ring is about 5mm, increasing to around 60mm in the rings nearer to Saturn. They also found that in general, smaller particles were present at the ring edges influenced by a close moon – such as the Encke Gap, and the edges of the A and B rings. The theory is that gravitational stirring from a nearby moon leads to faster, harder collisions between the particles at the ring edge, smashing them apart and so creating a population of smaller icy particles. On the other hand, the edges of the narrow ringlets within the Cassini Division and the C ring show weak diffraction signatures, indicating that the particles there are on the whole much larger.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *Sizes of the smallest particles at Saturn's ring edges* by Stephanie Eckert, Joshua E Colwell, Tracy M Becker and Larry W Esposito.
Read it online at: https://doi.org/10.1016/j.icarus.2020.114224

NASA/JPL-CALTECH, NASA/ESA/Z. LEVAY AND R. VAN DER MAREL/STSCI/T. HALLAS AND A. MELLINGER

When galaxies collide

A simulation predicts how the Milky Way will meet its end at the hands of neighbouring galaxy, Andromeda

Our Milky Way is on a collision course. In roughly 4.5 billion years' time, it will smash into the rapidly approaching Andromeda Galaxy, and this month's paper gives us the most accurate idea yet of what will happen next.

That such a collision is inevitable has been known for a little while. It has long been clear from measurements of the Doppler shift of its spectral lines that Andromeda was approaching, but such measurements can only tell you about the motion directly towards or away from the observer. Working out if we were in for a direct hit or a near miss therefore required careful study of the motion of Andromeda's satellite galaxies, and they reveal Andromeda's trajectory makes collision inevitable.

Plugging this information on the relative velocities, estimates of the masses of the galaxies and details of their structure into their model, the researchers watched the collision unfold. Though the details depend to some extent on galactic structure and in particular on assumptions we make about the haloes of dark matter that contain the visible discs of the Milky Way and Andromeda, the general picture is clear. After a spectacular series of close passes lasting billions of years – and which will distort the structure of both galaxies – a final merger will occur roughly 10 billion years from now.

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

"After a series of passes which will distort the structure of both galaxies – a final merger will occur about 10 billion years from now"

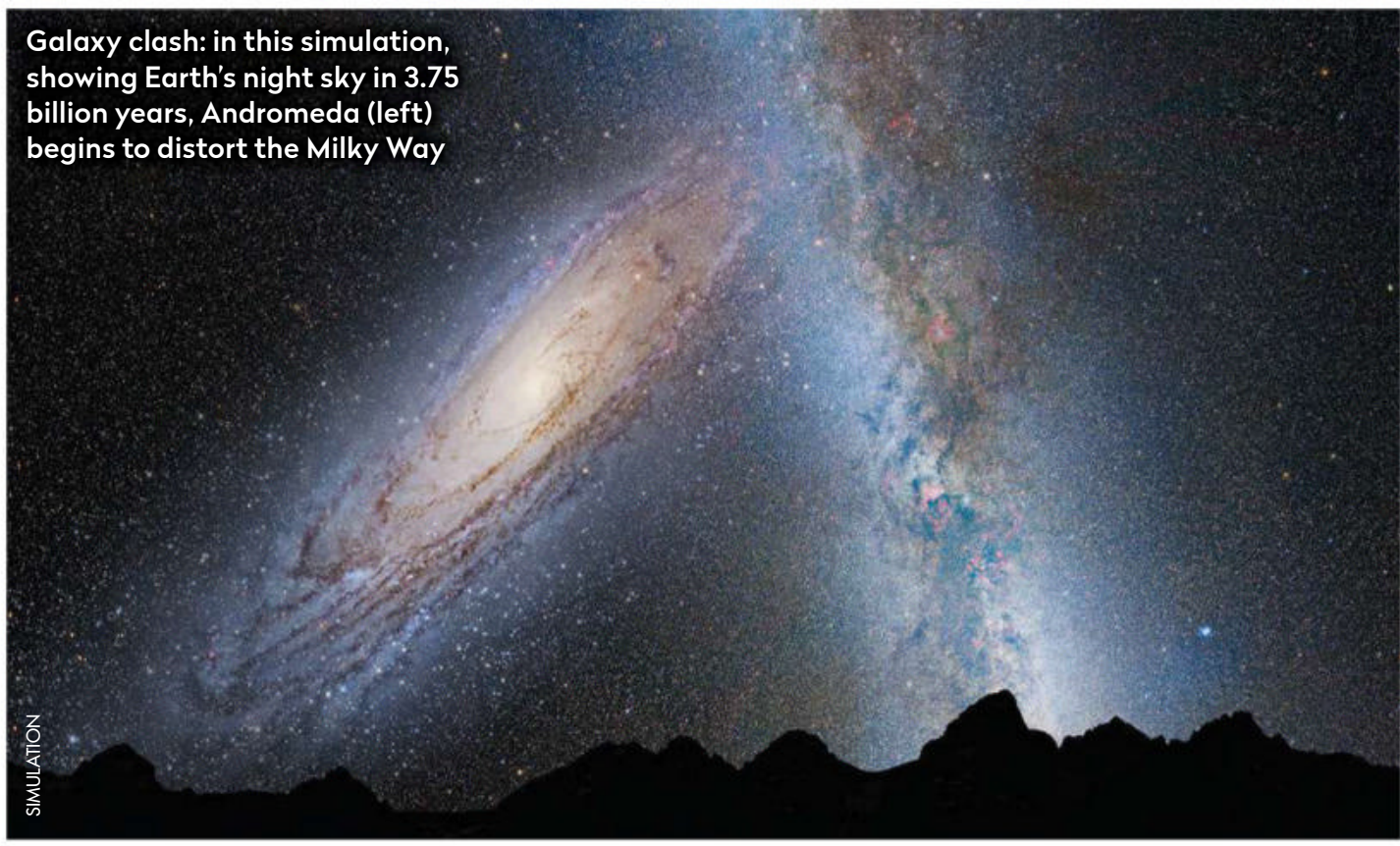
Forming a new galaxy

The result is a new, larger galaxy, which they call 'Milkdromeda' (There's something about this name that really bugs me – surely, we need something grander sounding? Suggestions from *BBC Sky at Night Magazine* readers are welcome). Rather than being a spiral like its forebears, this new system ends up as a giant elliptical.

For the first time, this simulation includes details of what happens to the supermassive black holes that lurk at both galaxy centres; the pair will end up forming a binary at the heart of the new, larger galaxy. This binary isn't stable, though; interaction with their surroundings means that the pair will spiral inwards, emitting gravitational waves as they do so. In only about 17 million years, the two will be close enough that the loss of energy through these gravitational waves drives a final inward spiral and merger.

The gravitational wave signal of an event like this can't be detected by LIGO (the Laser Interferometer Gravitational-Wave Observatory), which is sensitive only to the merging of lower mass black holes and neutron stars. In the future, the simulations indicate that ESA's LISA (Laser Interferometer Space Antenna) mission should observe such mergers out to an approximate redshift of two – so in a decade or so we may be able to see how predictions of the fate of the Milky Way's black hole match up to similar events elsewhere.

The paper ends on a melancholic note: the authors' estimate of 10 billion years for the merger to reach its end is longer than in previous studies, but means that the Sun will not live long enough to find a home in the new galaxy. We'll have to enjoy the results of simulations instead.



Galaxy clash: in this simulation, showing Earth's night sky in 3.75 billion years, Andromeda (left) begins to distort the Milky Way

Chris Lintott was reading... *Future merger of the Milky Way with Andromeda galaxy and the fate of their supermassive black holes* by Riccardo Schiavi et al. **Read it online at: https://arxiv.org/abs/2102.10938**

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT

As three missions reach Mars, we look back at what Patrick Moore said about the planet and the first mission to orbit it, Mariner 9

▲ Mars in detail: Mariner 9 (inset) took many photos of the Red Planet's features, including this 1972 image which shows the central caldera of the mighty volcano Olympus Mons

Although I cannot remember the time when Mars was believed to be inhabited, my memory does go back to when our ideas about it were very different. The dark areas were vegetation tracts; the white polar caps were due to a thin layer of solid carbon dioxide; the surface was fairly uniform, with no high mountains or valleys; the atmosphere was made up chiefly of nitrogen; the red regions were deserts, covered with sand of the type you find at Bognor Regis. In fact, all these assumptions were wrong.

The great breakthrough in our understanding of Mars was due to two spacecraft, Mariner 4 and above all Mariner 9, the orbiter that flew around Mars in 1971.

The Mariner 4 mission of 1964 had sent back 21 images and these were good enough to show that the surface was more interesting than had been expected. There were mountains and valleys, though canals were conspicuous only by their absence. The dark regions were not due to vegetation; they were regions where the reddish material had been blown away by winds exposing the darkness beneath. Mariner 6 sent back 75 photographs while Mariner 7 managed to produce 126 images, mainly of the southern hemisphere, before contact was lost.

All of the other pre-1971 probes originated from the USSR, but little data was received, and the only thing landed on Mars was a Soviet pennant. It is strange that even now the Russians have had no luck with Mars, particularly as they have been so successful with Venus, which should have been a more difficult target.

Exploring the Red Planet

Mariner 9 was launched on 30 May 1971 on an Atlas-Centaur rocket. It reached Mars less than six months later and went into orbit, ready to begin analysing the atmosphere and mapping the surface.

All went well but NASA's planners had no control over one factor – Martian dust storms. These are common enough, and can become global. When Mariner 9 arrived, one of these storms was in progress

and the surface features were hidden. Gradually the dust settled and gave us views showing that by sheer bad luck, Mariners 6 and 7 had imaged the planet's least spectacular part. Mariner 9 had plenty to do, particularly because of the failure of its twin, Mariner 8.

The images it sent back showed details of all kinds. There was a vast system of canyons, over 4,000km long, now known as the Valles Marineris. But perhaps the most striking of all were the volcanoes, some of them dwarfing any volcanoes of Earth. Loftiest of all is Olympus Mons, towering 25km above the land below and topped by an enormous, complex caldera. Another feature of special interest is Hellas, south of the Syrtis Major. It is circular and becomes so bright that it looks like an extra polar cap. It had been regarded as a snow-covered plateau – in fact it is a deep basin that can be filled with white clouds.

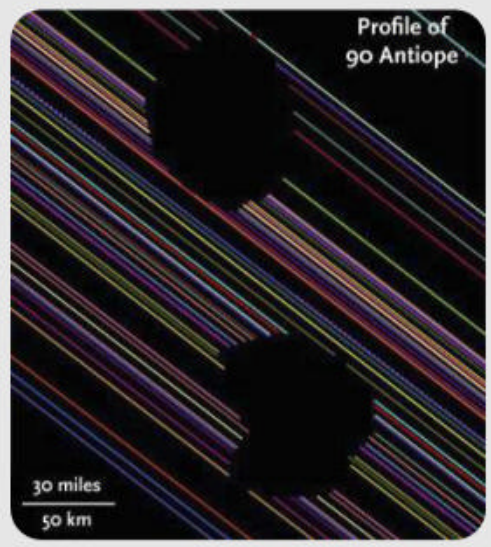
Mariner 9 sent back its last signals on 27 October 1972 and continued in its orbit, silent and undetectable. It will not be a permanent member of the Solar System as around 2022 it will enter the Martian atmosphere. It has done its work better than its makers had dared to expect and it has an honoured place in scientific history.

This article was originally published in BBC Sky at Night Magazine in May 2011.

Looking back: The Sky at Night

5 April 1978

On the April 1978 episode of *The Sky at Night*, Patrick Moore was taking a look at the asteroid 4 Vesta, the second largest object in the asteroid belt behind dwarf planet Ceres. He was joined on the show by Gordon Taylor, an astronomer from the Royal Greenwich Observatory at the time and a pioneer in the field of asteroid occultations.



▲ Occultation data from 2011 reveals the size of 90 Antiope

An occultation occurs when a Solar System object moves in front of a more distant object. In the 1950s, measurements of asteroid orbits were accurate enough that Taylor could now predict when an asteroid would occult a background star. When this happened, it would cause the star to dim, or even wink out altogether, for a fraction of a second as the asteroid passed across it. Taylor spent much of his career precisely measuring how long the asteroids blocked the light during an occultation, as by combining this with the asteroid's speed he could gain an accurate measure of its size. Over the years, Taylor made several measurements of several of the larger objects of the belt – Ceres, Pallas, Juno and Vesta.

Today, the field has become increasingly sophisticated with groups of astronomers from all over the world working together, accurately measuring the occultations of asteroids. By putting dozens of measurements together, it's possible to determine not just the size of an asteroid, but also its shape as well.

The Sky at Night returns

After a well-earned break, *The Sky at Night* is back on our screens this month with more of the latest discoveries in space science and practical astronomy guides. This episode Maggie, Chris and the rest of the team look at the big stories from the past few months, including the successful landing of NASA's Perseverance rover on the surface of Mars.

BBC Four, **11 April**, 10pm (first repeat BBC Four, **15 April,** 7:30pm)
Check www.bbc.co.uk/skyatnight for more up-to-date information

▲ In February NASA's Perseverance rover captured its first image of Mars

Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

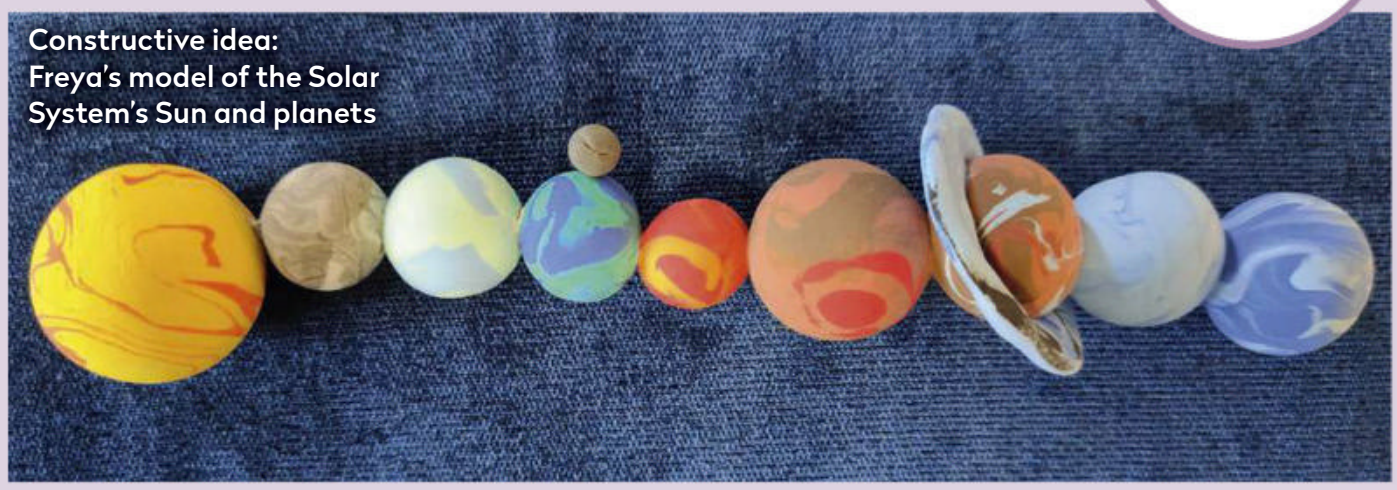
Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

This month's top prize:
four Philip's titles

PHILIP'S The 'Message of the Month' writer will receive a bundle of four top titles courtesy of astronomy publisher Philip's: Ian Ridpath and Wil Tirion's *Star Chart*, Robin Scagell's *Guide to the Northern Constellations*, Heather Couper and Nigel Henbest's *2021 Stargazing*, and a planisphere for the night skies as they appear at latitude 51.5° north.

Winner's details will be passed on to Octopus Publishing to fulfil the prize



Constructive idea: Freya's model of the Solar System's Sun and planets

Lockdown project

My eight-year-old granddaughter, Freya, loves getting involved with my astrophotography. Remotely, she helps me to control the mount during setup, then sits back and stares intently at the screen as the mount automatically moves into position and the images start to come in.

However, like many children during lockdown she is suffering from not seeing her friends, her grandparents and not being able to help me with my imaging. So she decided to keep up her astronomy skills by making a model of the Sun and planets of our Solar System. I especially love the addition of Earth's Moon, Jupiter's Great Red Spot and the fact that, correctly, Pluto doesn't make an appearance.
Jim Hunt, Poynton, Cheshire

What fantastically detailed, fun planets those are, Jim! Let's hope Freya can assist you with your astrophotography in person again soon. ***– Ed.***

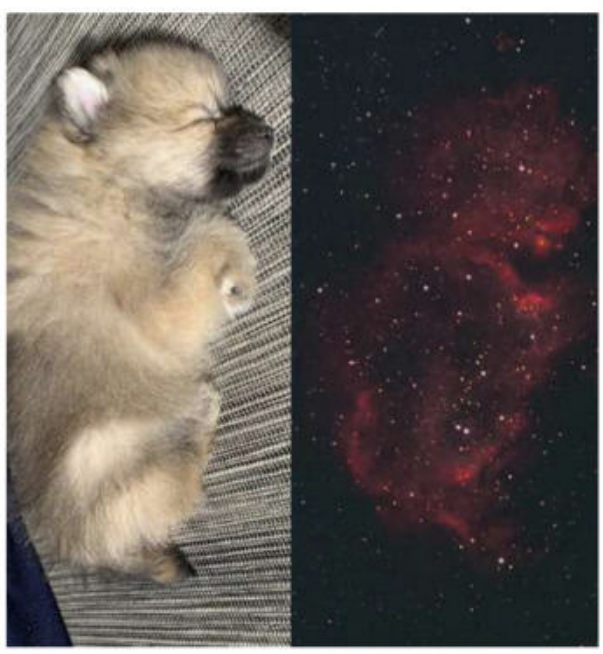
Searching for life

I believe that the search for life on the Red Planet is destined for disillusionment if we do find it. Surely, because of the flow of meteoric material between Earth and Mars, any life on Mars is (or was) likely to share an origin with life on Earth, and be DNA-based. In essence, therefore, the discovery of life on Mars will not answer the question, 'Are we alone?' If we are to find an independent evolution of life, it will have to be in an environment isolated from asteroid and meteorite impacts, like the ocean moons of Jupiter and Saturn, for example.

I can't recall seeing this argument put forward anywhere, and I would love someone to tell me I am misguided.
Cliff Webb, Farnham, Surrey

Dog stars?

A bit of fun in the current times... After imaging a wide-field shot of the Heart and Soul Nebula, I couldn't help seeing an uncanny resemblance between the Soul Nebula and my puppy, Percy.
Dan Fleetwood, via email



Tweet

Barry Clough
@CloughBarry • Feb 21
Can't decide which one I prefer, but patience paid off as an airliner passed directly in front of the Moon. @skyatnightmag #moon

Steve's lunar phase calculator

Moon model

I thought you might like to see the lunar phase calculator that I made following Mark Parrish's article in the December issue ('DIY Astronomy', December 2020 issue, page 74). Though I made some modifications I kept to the original closely. Having now made one in wood I will attempt to make one in brass.
Steve Harrison, via email

Webinar tips

I just wanted to say I really enjoyed the *BBC Sky at Night Magazine* webinar with Tom Kerss in January – 'How to Use a Telescope Like a Pro'. I'm new to astronomy; my boyfriend treated me to a Sky-Watcher Heritage telescope as a present for my birthday last April and since then I've been learning the ropes.

The webinar really helped me to understand the technical details of my scope's capabilities. Tom even spent much longer than planned answering people's questions and explained things really clearly for beginners like myself. He even helped me on Twitter with a couple of additional questions I had the following day. I'd welcome another amateur astronomy workshop from Tom if you're able to do one!
Stephanie Staszko, Cheshire ▸

ON FACEBOOK

WE ASKED: Who would you like to meet most from the history of astronomy or spaceflight?

Michael Henty Isaac Newton. Understanding his laws of motion got us in the air, into space, on the Moon and all the way to Mars to land a Meccano rover in the middle of a crater. He was a bit touchy when it came to science, so I think I'd keep the subject well away and ask him how his apple orchard is getting on.

Andrew Ball There is only one person who has met Orville Wright (first human to take flight), Yuri Gagarin (first human in space) and Neil Armstrong (first human to step foot on the Moon). To ask him, Sir Patrick Moore, how to achieve such monumental stratospheric goals would be an honour.

Carol Miller I would choose Helen Sharman and I'd talk to her about the time she did her astronaut/cosmonaut training and her subsequent space flight to the Mir Space Station.

Mark Wade Copernicus. Without his foresight we wouldn't know anything about space.

Nomis Bennett Neil Armstrong; I'd want to know everything about the Moon landing.

Davy Moore The legendary Albert Einstein, a real genius. I did, however, meet Professor Stephen Hawking in 1997.

Sara Courtley Thomas Wright (1711–86) from County Durham. I live where he did in Byers Green and I am obsessed with him and what he did for the astronomical world. He was first to describe the shape of the Milky Way! I'd like to just sit and talk to him about his adventures and what living here was like in his day.

SCOPE DOCTOR

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scopedoctor@skyatnightmagazine.com

I have a Sky-Watcher SkyMax 127 and a variety of eyepieces, a 2x Barlow lens and an erecting prism, but I struggle to see the planets. Am I doing something wrong?

KEVIN MASTERS

◂ The SkyMax 127 is good for planetary observing

The SkyMax 127's 1,500mm focal length makes it a good choice for lunar and planetary observations, but planets will appear quite small in the field of view. Planetary observers often use magnifications of between 110x and 150x, although some planets respond better to higher magnifications than others. Jupiter, for example, is probably best viewed at lower magnification, but Saturn can take greater magnification. It is far better to view a smaller, sharp image than a larger blurry one and the key to planetary observing is to take your time and take advantage of atmospherically still moments.

Your William Optics 9mm eyepiece would produce the maximum magnification that I advise with this instrument in the best of conditions, and for lower magnification the 25mm with the 2x Barlow lens would be suitable.

In addition to good seeing conditions, accurate focus and mount stability are crucial to good planetary observations. I would be tempted to suspend some weight from the centre of the mount to dampen down vibrations.

Steve's top tip

What is an erecting prism?

Placing a normal eyepiece straight into the focuser of a Newtonian reflector, refractor, Schmidt-Cassegrain (SCT) or Maksutov-Cassegrain telescope produces an upside-down image. However, all but Newtonian reflectors are normally used with a star diagonal to make the viewing angle more comfortable and this will correct the image vertically but flip it side to side! If you absolutely must have a correctly orientated view or you want to use your astronomical telescope for terrestrial observing then you can use a special diagonal containing an Amici prism, which will present a correctly orientated view in refractors, SCTs and Maksutov-Cassegrains.

Steve Richards is a keen astro imager and an astronomy equipment expert

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EDITORIAL
Editor Chris Bramley
Art Editor Steve Marsh
Production Editor Neil McKim
News Editor Ezzy Pearson
Staff Writer Iain Todd
Reviews Editor Paul Money

CONTRIBUTORS
Wallace Arthur, Stuart Atkinson, Nisha Beerjeraz-Hoyle, Shaoni Bhattacharya, Jamie Carter, Charlotte Daniels, Lewis Dartnell, Glenn Dawes, Pippa Goldschmidt, Mary McIntyre, Pete Lawrence, Chris Lintott, Jonathan Powell, Steve Richards, Colin Stuart, Steve Tonkin, Jane Williamson, Jenny Winder

ADVERTISING SALES
Advertising Manager Sam Jones +44 (0)117 300 8145, sam.jones@immediate.co.uk
Inserts Laurence Robertson +353 (0)87 690 2208

PRODUCTION
Production Director Sarah Powell
Production Coordinator Lauren Morris
Ad Services Manager Paul Thornton
Ad Coordinator Charles Thurlow
Ad Designer Parvin Sepehr
Reprographics Tony Hunt, Chris Sutch

LICENSING
Director of Licensing and Syndication Tim Hudson
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Head of Circulation Rob Brock
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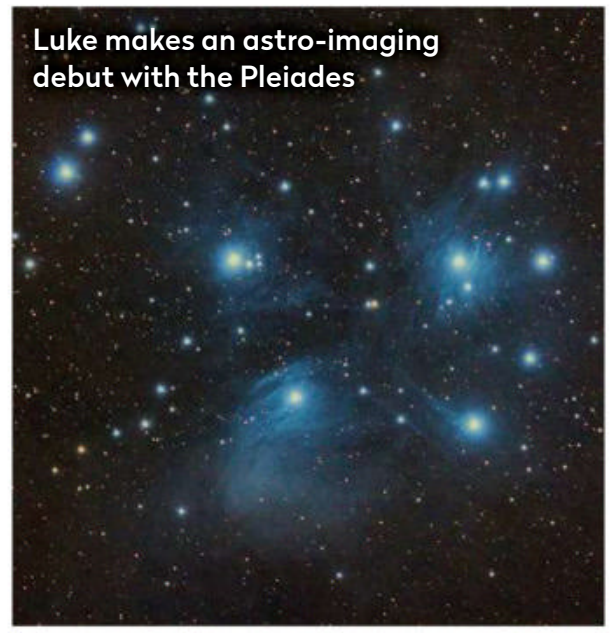
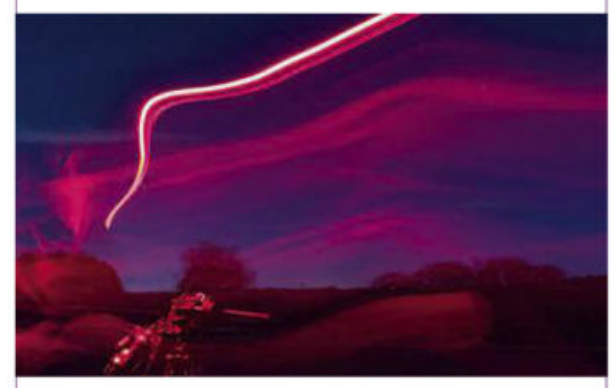

Luke makes an astro-imaging debut with the Pleiades

Star cluster starter

▸ I've always been fascinated with astronomy and during lockdown last year I decided to take my stargazing up a notch and get into astrophotography. After six months of self-teaching and building a setup, watching endless YouTube videos, several failed attempts and some advice from a friend, I finally got a respectable image of the Pleiades star cluster (above). I absolutely love it and I'm hooked. This is 135x 30-second exposures, 30x flat frames, 30x bias frames and 30x dark frames; stacked in DeepSkyStacker, stretched in Astro Pixel Processor and finished off in Photoshop. I hope you like it!
Luke Hurren, Portsmouth

Instagram


astrophotoben • 1 February 2021



Whilst I edited a timelapse of the Horsehead Nebula, I noticed I had accidentally made some abstract art. Please enjoy some long exposure light trails. A single 6-second exposure taken with a Nikon D5600 and Sigma 20mm f/1.4 lens. Edited with Lightroom, Photoshop and Topaz DeNoise AI. #nasa #space #astronomy #astrophoto #astrophotography @bbcskyatnightmag @sigmauk @astronomypicturesdaily

CORRECTIONS

• Last month's Message of the Month ('Interactive', March 2021 issue, page 20), entitled 'Horsehead hunt', was from Jim Latham of Anglesey, not Richard Bleasdale of Birmingham.

SOCIETY IN FOCUS

Bridgend Astronomical Society (BAS) in South Wales reaches its 40th birthday in 2021 and we hope to enjoy it in celebratory fashion! Founded in 1981 by Joan Hawkins, Laurie Brophy and Frank Morris, the Bridgend Amateur Astronomical Society, as it was called, welcomed all who were interested in the night sky; attendance at a meeting back then cost a whopping 30p, including tea and a biscuit! It's been a pleasure to welcome back co-founder Joan Hawkins, who after a short break is supporting our team to make sure all 90-plus members get the same welcome and support they would have back in 1981.

Over the past year BAS has grown rapidly with social media, Zoom presentations, newsletters and socially distanced observing events. We've been serving up quiz nights and our educational courses have been popular too. An eight-week beginners' course has already run twice. The BAS has developed a close-knit feel and members can look forward to many more events such as a Rocket Science Day, workshops and star parties when the pandemic subsides.


▲ The Bridgend Astronomical Society has a welcoming and supportive ethos

We have a record number of junior members this season. Through BAS Josh, aged 7, recently received a personal message from his hero Tim Peake, congratulating him on his fantastic project on Mars! We're confident BAS will continue to thrive for the next 40 years.
Jason Mead, vice chair & observation officer, Bridgend Astronomical Society
▸ www.bridgendastro.org.uk

COVID-19
Online and socially distanced events taking place this month

We pick the best astronomy events and resources available online this month

WHAT'S ONLINE

DOCUMENTARY
The Jupiter Enigma
As Juno approaches the end of its 10-year mission, it's a good time to catch this short but fact-packed documentary based on NASA's latest findings about the behemoth planet that shaped our Solar System.
Available on Amazon Prime

ONLINE TALKS
Great Comets and Great Disappointments
Hampshire Astronomical Group hosts this public lecture by Nick James on comets: unpredictable and sometimes spectacular, what makes some comets 'great'? The free event takes place on 9 April at 7.30pm. Book your place in good time and contact **lindy.bryant@hantsastro.org.uk.**

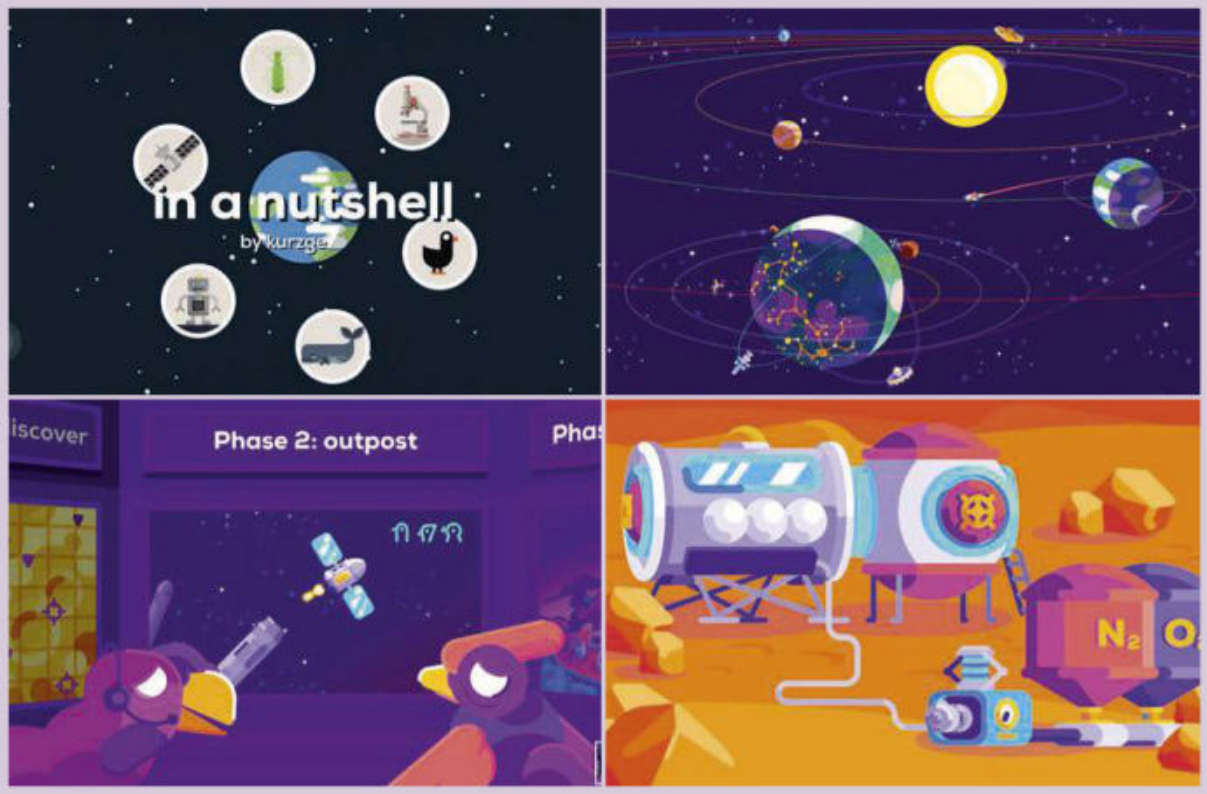
Exploring Astronomy through Philately
Join Katrin Raynor-Evans on 10 April at 7pm for an enlightening talk on stamps from around the world and how they have celebrated milestones in astronomy and spaceflight. Newtown Astronomy Society hosts the event via Zoom, which is free to members and £2 for guests (contact the secretary at **newtownastrosoc@gmail.com** in advance to request entry).

The Geology of Venus
On 22 April, Dr Peter Grindrod from the Natural History Museum takes a look at the landscapes and geology of Venus. It's part of an ongoing series exploring the geology of our Solar System, so keep an eye out for more. The free online talk begins at 5pm. **bit.ly/3qgKPU4**

ONLINE COURSE
High Energy Astrophysics
How does a black hole form? What's going on in active galaxies? How do we explain gamma-ray bursts? You'll know all about the most powerful phenomena in the Universe after this five-month distance learning course from the Astrophysics Research Institute; and no prior specialist maths and science background is required. With a cost of £225, it starts on 15 June with a sign-up deadline on 31 May.
https://astronomy.ac.uk/info/energy

PODCAST
Kielder Observatory Podcast
Public events have been seriously hit at Kielder of late, but you can still catch up with their latest news, plus space chat and night-sky target tips in this monthly podcast.
https://podfollow.com/kielderobs/view

PICK OF THE MONTH



▲ A cartoon network: 14 million-plus subscribers have signed up for answers to top science topics

Kurzgesagt – In a Nutshell
Bite-sized animations that try to answer some of the big questions

Don't let the child-friendly cartoon style fool you; Kurzgesagt – In a Nutshell is a YouTube channel tackling some deep scientific questions, with dozens of videos on space themes. Carefully and widely-researched, with witty scripts that owe no small debt to Douglas Adams, they've attracted over 14 million subscribers.

Sidestepping well-worn topics in favour of a more original slant, videos include: Building a Marsbase is a Horrible Idea; Let's Do It; Could Solar Storms Destroy Civilisation?; What if Earth got Kicked Out of the Solar System?; and Why Black Holes Could Delete the Universe.
www.youtube.com

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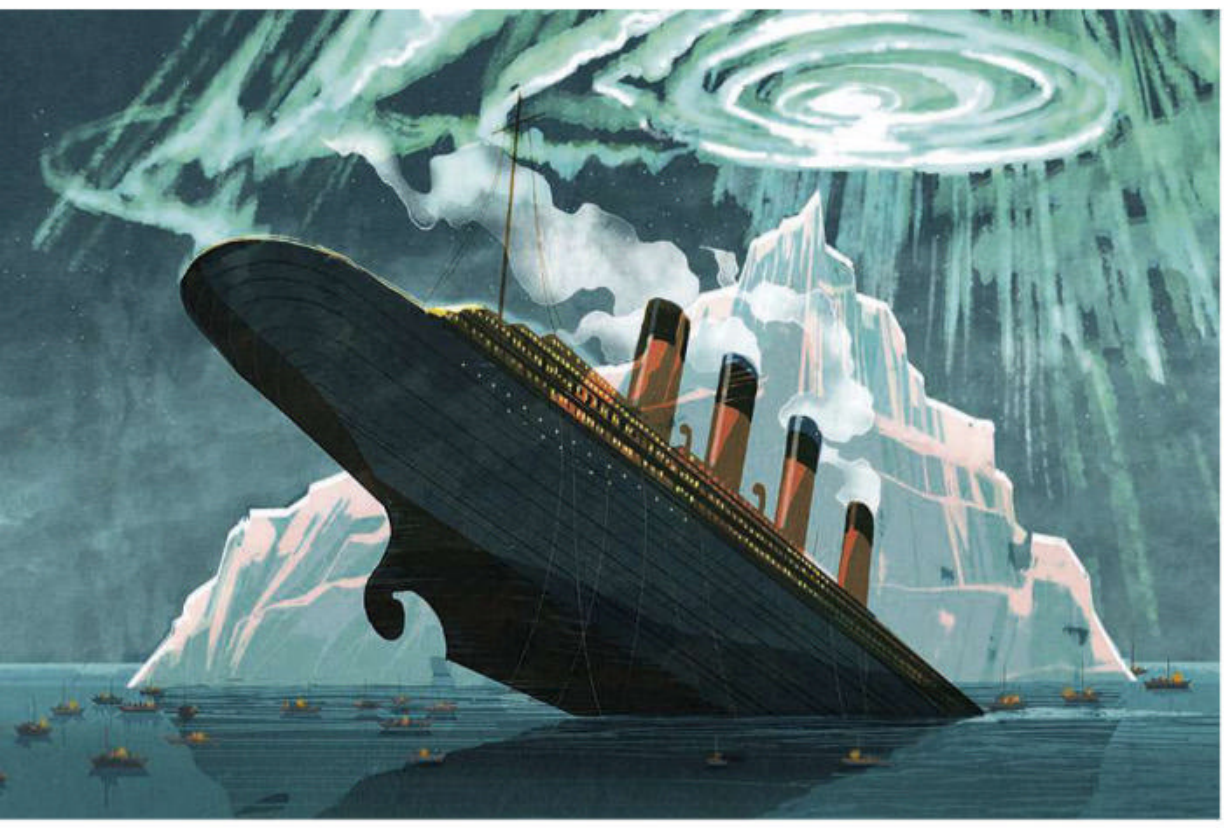
FIELD OF VIEW

The Northern Lights and the *Titanic*

New evidence suggests that a solar storm may have affected the ship's equipment



Jonathan Powell is a freelance writer and broadcaster. A former correspondent at BBC Radio Wales, he has written three books on astronomy and is currently astronomy columnist at the *South Wales Argus*

The story of *RMS Titanic* is one that has been retold countless times following the fateful night of its sinking. During the early hours of 15 April 1912, White Star Line's new 'Olympic' class liner ploughed into an iceberg with tragic consequences. In the hours that followed, more than 1,500 souls were lost.

The *Titanic* continues to generate an unprecedented level of interest, with newly discovered evidence giving more insight into the tragedy. Many factors seem to have conspired to seal its eventual doom: consider the fire that blazed uncontrollably in one of its coal bunkers before and after it left Southampton, which could have compromised the integrity of one of the watertight compartments; or the disappearance of binoculars that were supposed to be at the disposal of the two-man crew in the crow's nest.

Last year new evidence was published in the journal *Weather* from independent weather researcher Mila Zinkova. Noting multiple eyewitness accounts she suggested that a geomagnetic storm, powerful enough to cause auroral activity at the latitude the *Titanic* struck the iceberg, may have affected the ship's onboard compass and telegraph equipment, leading to errors in determining location and urgent 'CQD' distress calls [a forerunner to SOS in Morse code] not reaching their intended recipients.

The *Titanic* sank two hours and 40 minutes after the collision, with *RMS Carpathia* arriving first on the scene some three to four hours later. James Bisset, second officer on the *Carpathia*, wrote in his log around one hour before *Titanic* hit the iceberg, "There was no Moon, but the Aurora Borealis glimmered like moonbeams shooting up from the northern horizon."

Responding to the *Titanic*'s distress signal, *Carpathia* had received incorrect coordinates for the stricken ship. Zinkova, who has written several papers on the *Titanic*, has theorised that compass readings had been thrown off by the interference caused by a solar flare. Nevertheless, *Carpathia* still succeeded in sailing directly to the *Titanic*'s drifting lifeboats. In a rather bizarre twist, Zinkova attributes this feat to the solar storm-induced compass errors cancelling out the misstated coordinates.

Storms of this nature are known to cause disruption to telecommunications, specifically in radio navigation systems, potentially altering the trajectory of radio signals. When the solar wind mixes with the ionosphere, it becomes super-ionized, causing destructive interference. The turbulence in some instances causes broadcasts to be picked up hundreds or even thousands of kilometres from the source of transmission. Such havoc can also block transmission completely.

Bisset's log book entries also state that the aurora was still going strong as the *Carpathia* neared the lifeboats, describing "greenish beams" in the night sky. Survivors concur with Bisset's logs and describe sighting the Northern Lights from their lifeboats. One survivor, Lawrence Beesley, recounted that the aurora, "...arched fanwise across the northern sky, with faint streamers reaching toward the Pole-star."

Whether or not a solar storm caused such interference remains inconclusive, but along with a vast array of theories and perhaps yet to be discovered evidence, the story of the *Titanic* remains very much an unclosed chapter in maritime history.

ALEX GREEN/FOLIO

BBC

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BBC Sky at Night MAGAZINE

In a new light: astronomers are challenging established views about Type Ia supernovae

ILLUSTRATION

Impossible STARS

For decades astronomers have relied on the uniform size of Type-Ia supernovae to help them measure the Universe. **Colin Stuart** looks at the impossible stars that cast doubt on the cosmic ruler

How do astronomers measure distances in space? We're yet to send anything beyond the outskirts of the Solar System and yet we regularly talk with confidence about how far away distant stars and galaxies are.

Charting celestial distances relies on a tool called the 'cosmic distance ladder', which is actually a range of different interconnected techniques (see box, page 34). One of the main methods is to use standard candles – astronomical objects that have a consistent inherent brightness. The dimmer they appear to us compared to this true brightness, the further away they must be.

▲ **Subrahmanyan Chandrasekhar calculated the mass limit for white dwarf stars in the 1930s**

Among the most common standard candles is a type of exploding star called a Type Ia supernova. Back in the 1930s, 19-year-old physicist Subrahmanyan Chandrasekhar was travelling by boat from his home in India to study in Europe. During his three-week voyage he passed the time by thinking about objects called white dwarfs, which form when stars like the Sun die. Chandrasekhar calculated that there is a limit to how heavy they can be: 1.4 times the mass of our Sun, a threshold now known as the Chandrasekhar Limit. ▸

USIS/ISTOCK/GETTY IMAGES, BETTMANN/GETTY

"The detonations are thought to occur when a white dwarf merges with a neighbouring star or robs material from it by ripping gas away with its strong gravitational pull"

ILLUSTRATION

► "Above this mass a white dwarf cannot be sustained," says Surajit Kalita, from the Indian Institute of Science in Bangalore. "It will burst," he says. It is this explosion that we see as a Type Ia supernova. The detonations are thought to occur when a white dwarf merges with a neighbouring star or robs material from it by ripping gas away with its strong gravitational pull.

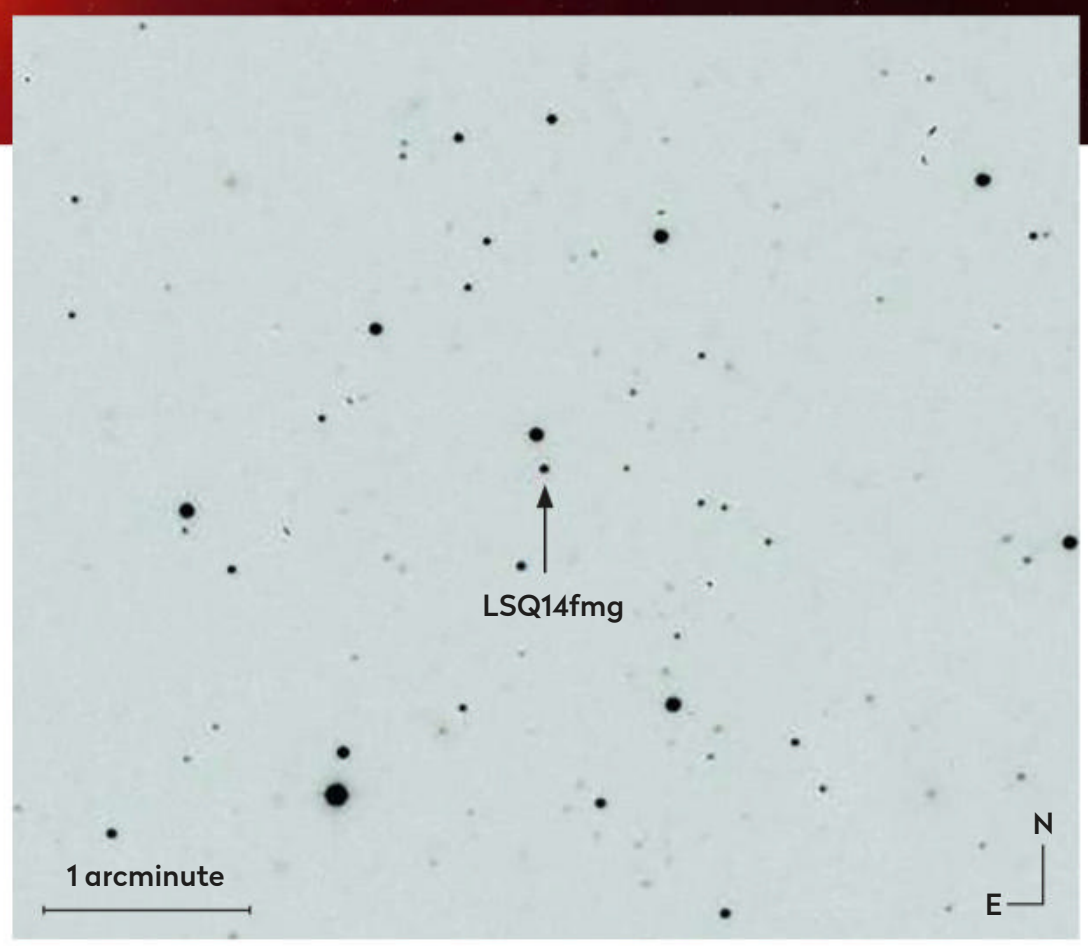
Exceptions to the rule

If all Type Ia supernovae are caused by white dwarfs with masses around the Chandrasekhar Limit, they should all detonate with the same amount of fuel. So they should all share a similar inherent brightness, too. Those that appear dimmer to us must be in galaxies that are further away. This is such a cornerstone of cosmology that astronomers used Type Ia supernovae to make a landmark discovery in 1998: the expansion of the Universe appears to be speeding up. Distant supernovae appeared dimmer than they should be, implying they've been carried further from us than we'd previously thought. The most common explanation for this is dark energy – a mysterious force increasingly pushing galaxies apart as the Universe gets bigger.

However, as is often the case, things aren't as simple as they first appear. Back in 2003 astronomers discovered something seemingly impossible – a Type Ia supernova with a brightness that suggested the sacred Chandrasekhar Limit had been breached. It was such a big deal that it was soon dubbed the 'Champagne Supernova' in reference to the Oasis song of the same name. Since then astronomers have discovered at least a dozen more of these rebellious rule-breakers; and some seem to have masses twice the Chandrasekhar Limit. If more of these 'impossible' stars are creeping into our data unseen, they could be throwing off our cosmic distance measurements. In turn it might even throw the whole idea of dark energy and the accelerating expansion of the Universe into doubt.

"We may need to modify or get rid of white dwarfs as standard candles," says Kalita. Thankfully, a flurry of recent research has sought to get to the bottom of this deepening mystery.

Just because we see a particularly bright supernova, it doesn't necessarily imply the white dwarf involved broke the Chandrasekhar Limit. In September, an international team led by Florida



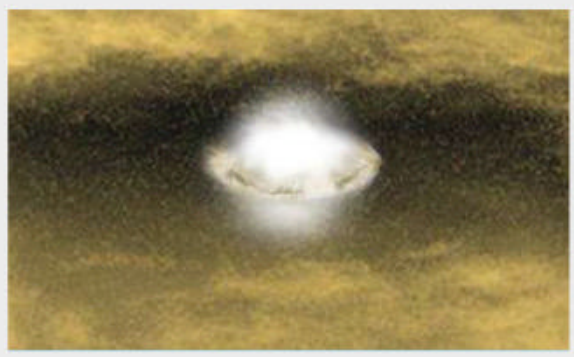
▲ Close scrutiny: the study of Type 1a supernova LSQ14fmg has led scientists to conclude that its 'super-Chandrasekhar' characteristics are a result of a star merging with a white dwarf

MARK GARLICK/SCIENCE PHOTO LIBRARY/ISTOCK/GETTY IMAGES, CARNEGIE SUPERNOVA PROJECT/LAS CAMPANAS OBSERVATORY, ESA/ATG MEDIALAB X 4, ASTRONOMY & ASTROPHYSICS (2020)

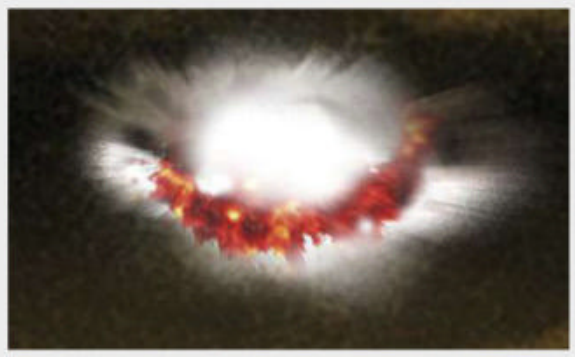
Type Ia supernovae

Greedy stars steal from their neighbours until they're ready to burst

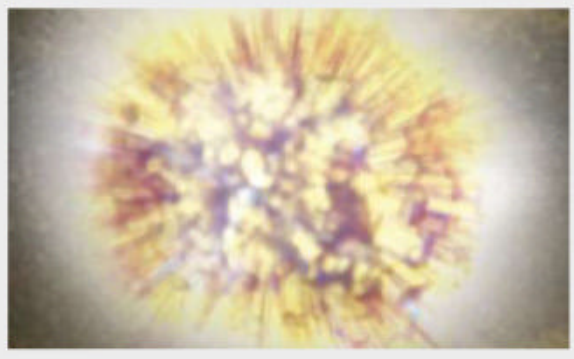
Step 1
Two stars are orbiting one another in a binary star system. One dies to become a dense white dwarf star. Its strong gravity allows it to steal material from its neighbour, increasing its own mass in the process.



Step 2
As the white dwarf's mass nears the Chandrasekhar Limit, the star shrinks under the new material's weight. As the pressure and temperature inside both rise, the white dwarf's carbon and oxygen fuse into iron.



Step 3
This turns the white dwarf into a fusion bomb, which soon detonates as a Type Ia supernovae. It's a cataclysm so bright that it can be seen halfway across the Universe and it will briefly outshine the entire galaxy it resides in.



Step 4
After the explosion, the supernova will fade over a period of days to weeks. The radioactive decay of ejected material allows us to tell the difference between a Type Ia supernova and other non-standard candles.

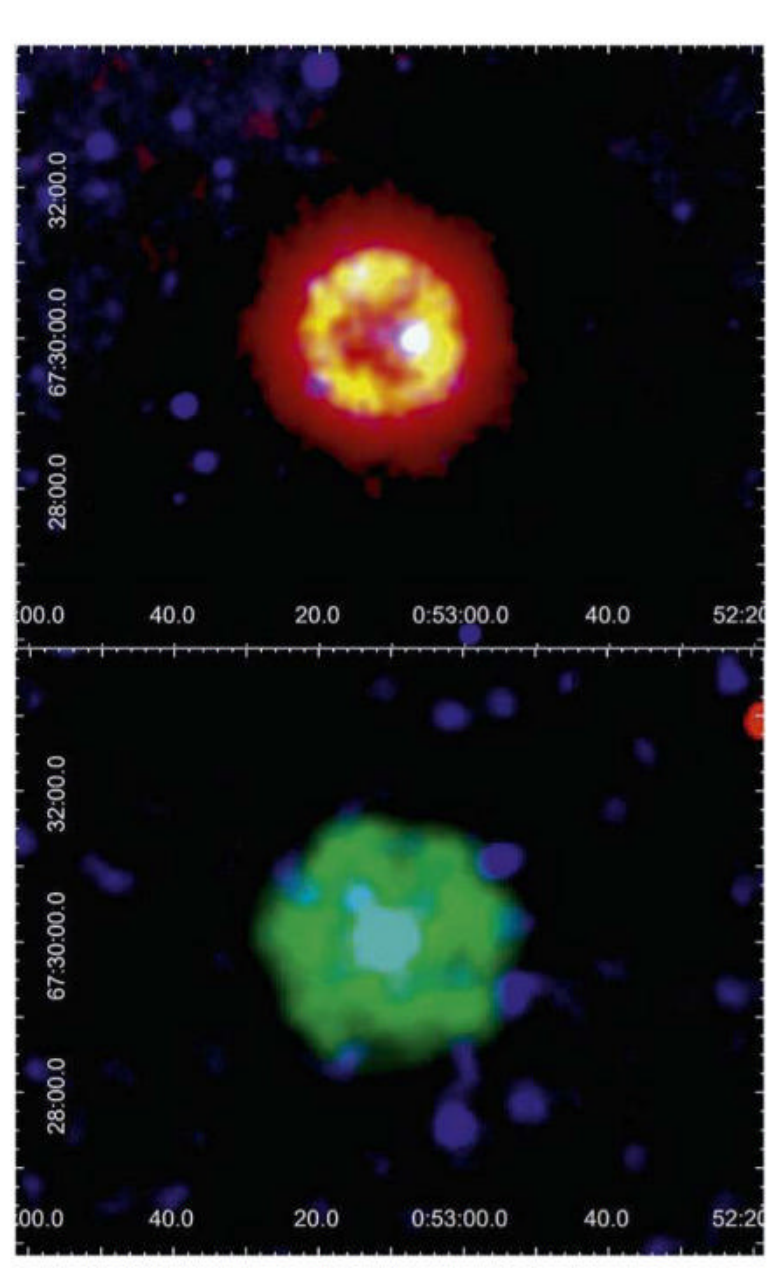
State University's Eric Hsiao announced their observations of an apparent 'super-Chandrasekhar' supernova called LSQ14fmg. They concluded that a star merged with a white dwarf, bulking it up to the Chandrasekhar Limit and forcing it to explode. The resulting supernova then crashed into material that had previously been ejected by the star before the merger, causing a spike in brightness. At no point did the white dwarf itself break the rules.

However, according to a team led by the University of Potsdam's Lidia Oskinova, that can't always be the case. In December she published her own observations of an object called IRAS 00500+6713. It's a central star embedded inside a giant gas cloud. "We saw something unexpected," she says. The central star appeared to be the product of a white dwarf ▸ merger that exceeded the Chandrasekhar Limit. It is a strong producer of X-ray radiation and analysis of those X-rays revealed it has shape-shifted into another type of star. "It exceeds the Chandrasekhar Limit because it isn't a white dwarf anymore," she says.

Had Oskinova's object really been a super-Chandrasekhar white dwarf it would have been the first time that anyone had ever seen one – so far their existence has only been deduced from the overly bright supernovae we've seen. Not seeing one yet has led many to come up with their own ideas about how these seemingly impossible stars can exist.

Testing theories

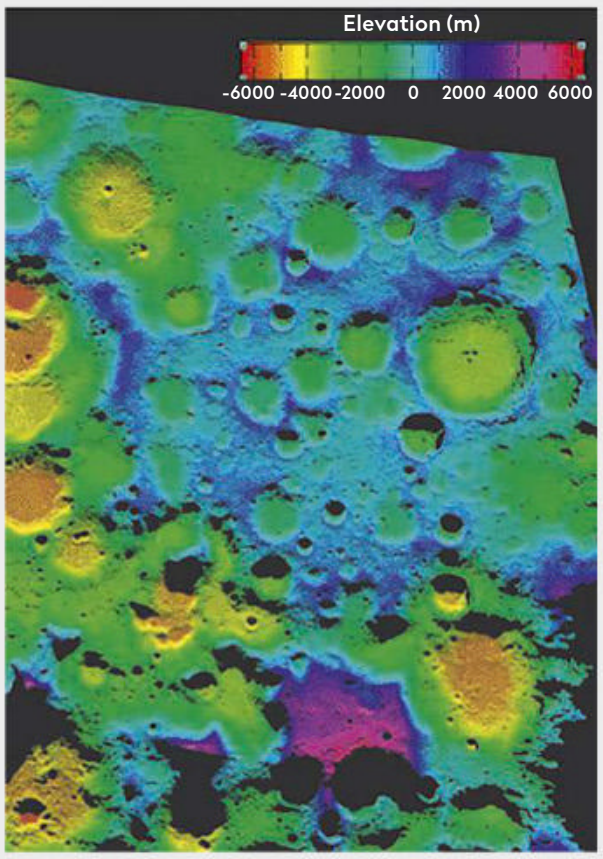
The waters are muddied by the fact that the Chandrasekhar Limit comes with a few caveats. To do the calculations back in the 1930s, Chandrasekhar simplified the situation. The idealised white dwarfs he considered were not rotating and did not have a magnetic field. In practice this is unrealistic as we know stars like the Sun spin and are intensely ▸



▲ Images of IRAS 00500+6713 in mid-infrared (top) and X-ray (below) wavelengths, appear to reveal a bright central star that may exceed the Chandrasekhar Limit

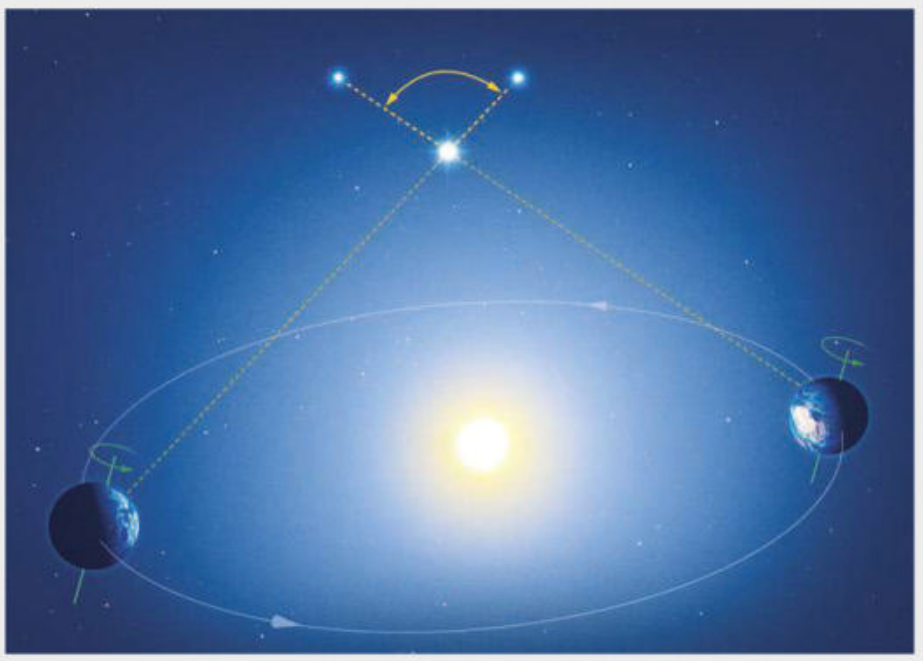
Measuring the Universe

Space is so vast that distances can't be measured with one method. So astronomers use several, the cosmic distance ladder



◁ Radar ranging. Distances up to 1 billion km

For distance measurements to objects in our Solar System (such as the Moon, left) we often bounce radio waves off their surfaces. The longer the waves take to return to Earth, the further away the object is.

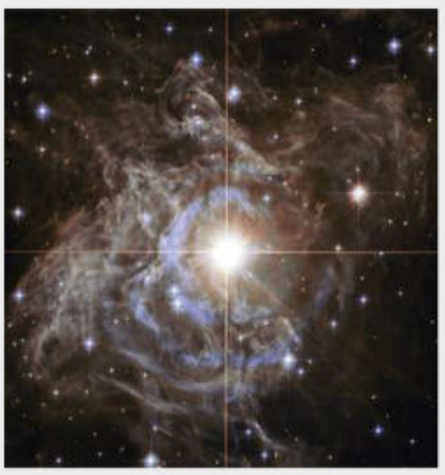


◁ Parallax. Up to 10,000 lightyears

Viewed six months apart, a foreground star appears to change position compared to one in the background. The closer the foreground one is to us the more it will jump, but beyond 10,000 lightyears away the change is too small to measure.

Cepheid variables. Up to 100 million lightyears ▷

These stars are another form of standard candle. They expand and contract in a regular way, altering their brightness. This cycle is longer for brighter Cepheid variables, giving us a way to know their true brightness, and to measure distances to nearby galaxies.



Tully-Fisher relation (TFR). Up to 15 million lightyears ▷

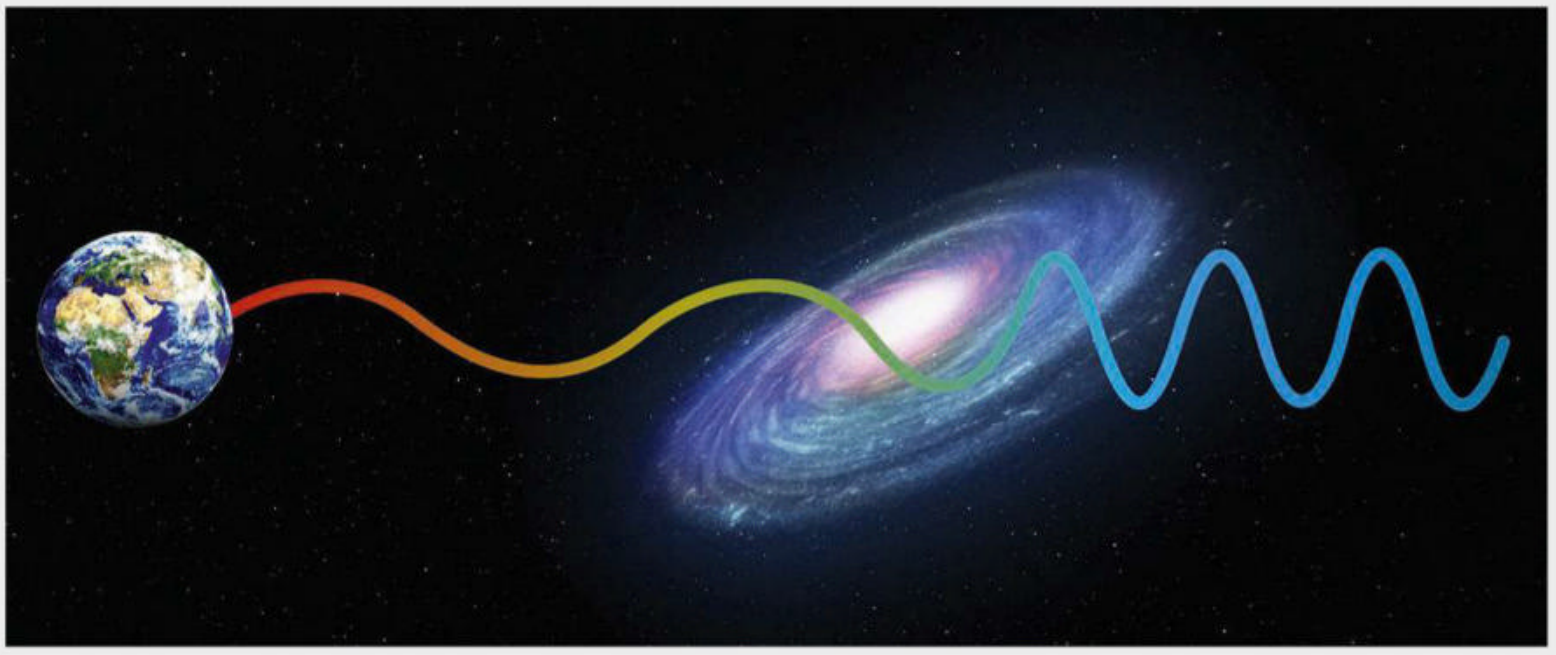
Brighter, more massive galaxies spin faster. We measure the rotation of a more distant galaxy by analysing its light spectrum. Like standard candles, the dimmer a galaxy appears compared to this true brightness, the further away it must be.


ILLUSTRATION

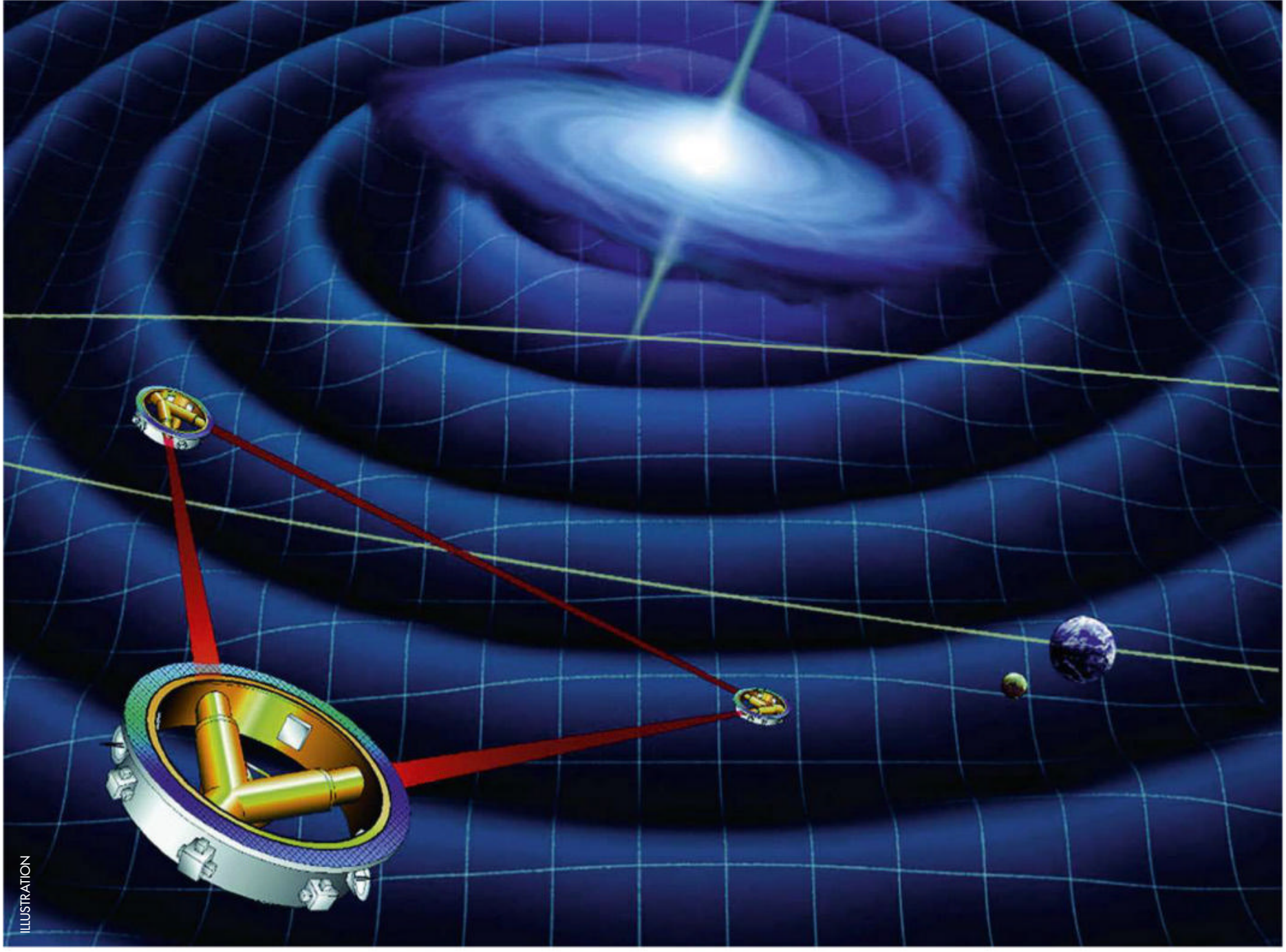
Redshift. Up to 1 bn lightyears ▷

The light from galaxies stretches out as the Universe expands, shifting it towards the colour spectrum's red end.

Edwin Hubble discovered that redshift increases with distance. To work out how far away the furthest galaxies are we just analyse their light.



RADARCON 2008, MARK GARLICK/SCIENCE PHOTO LIBRARY, NASA/ESA AND THE HUBBLE HERITAGE TEAM (STSCI/AURA)-HUBBLE/EUROPE COLLABORATION, ARVITALYA/ISTOCK/GETTY IMAGES, NASA



▲ Ripple effect: three LISA (Laser Interferometer Space Antenna) spacecraft are being launched in the 2030s, which will be able to measure the gravitational waves created by a moving white dwarf

► magnetic. These properties are only amplified as a star shrinks into a white dwarf at the end of its life.

A white dwarf exists in a delicate balance between gravity trying to collapse the star and the natural resistance its constituent particles have of being squashed too tightly together. To successfully exceed the Chandrasekhar Limit, we'd likely need at least one extra factor helping in the fight against gravity. Shin'ichirou Yoshida from the University of Tokyo thinks a rapid rotation is enough to do the trick. According to his computer models, spinning can double the mass the white dwarf can attain before exploding as a Type Ia supernova. Edson Otoniel da Silva, from the Instituto Tecnológico de Aeronáutica in Brazil, thinks it's magnetism. Indeed, his calculations show that a highly magnetised white dwarf can reach 2.14 solar masses.

Even those limits are fairly modest if you believe Sayan Pal, a researcher at the SN Bose National Centre for Basic Sciences in India. Chandrasekhar's original genius was to apply the fairly new field of quantum physics to white dwarfs. Pal believes a new quantum effect should be taken into account, one that would increase the white dwarf's natural resistance to gravitational contraction. Once you do that, he says, you can end up with white dwarfs more than three times more massive than the Chandrasekhar Limit.

Perhaps the most extreme solution belongs to Flavia Rocha, also from the Instituto Tecnológico de Aeronáutica. She believes we need to turn our ideas about gravity upside down to explain these impossible stars. Most cosmologists agree that the laws of physics are the same throughout the Universe – the force of gravity, for example, operates identically across the cosmos. However, we see stars at the edges of galaxies moving way too fast. So fast that they should escape the gravitational pull of the galaxy and fly off into space, but they don't. The usual explanation is that there is a lot of hidden material in galaxies, providing additional gravitational muscle – dark matter. Yet others argue in favour of modified gravity – that in some circumstances gravity operates differently than we're used to. When Rocha applied this idea to white dwarfs she found that it made the white dwarfs bigger, increasing their stability against collapsing and triggering a supernova. Her results are consistent with white dwarfs reaching up to double the Chandrasekhar Limit.

Solving the mystery

If we're to solve this mystery once and for all, we need to find a super-Chandrasekhar white dwarf. Surajit Kalita believes that there are experiments in the pipeline that will help us do just that, including the Laser Interferometer Space Antenna (LISA). Scheduled for launch in the 2030s, it is a space-based gravitational wave observatory. Gravitational waves are ripples created as objects move through space, just as objects generate waves as they move through water. Our existing gravitational wave observatories aren't sensitive enough to pick up the relatively small ripples from white dwarfs, but Kalita says LISA should be. "From the strength and frequency of the waves we can then measure a white dwarf's size," he says. In turn that can be used to model the white dwarf's rotation and magnetic field to see if they tally with the various predictions we've seen.

It can't come soon enough – nothing less than our understanding of the Universe depends on it.

Colin Stuart (@skyponderer) is an astronomy author and speaker. Get a free e-book at **colinstuart.net/ebook**

INTRODUCTION TO ASTROPHOTOGRAPHY

Your next step in astrophotography:

A STAR TRACKER

If you've started taking photos of the night sky and have reached a bit of a plateau, there's no need to buy a new camera or telescope... a tracker mount will work wonders, explains **Stuart Atkinson**

Open up any issue of this magazine and you'll see beautiful images of constellations, planets and deep-sky objects on its pages, many taken by readers. As light pollution increases, both around and above us, astrophotography – taking photos of objects in the night sky – is now the primary pursuit of many amateur astronomers who, instead of looking through their telescope's eyepiece, now use it as a camera to take portraits of the Universe.

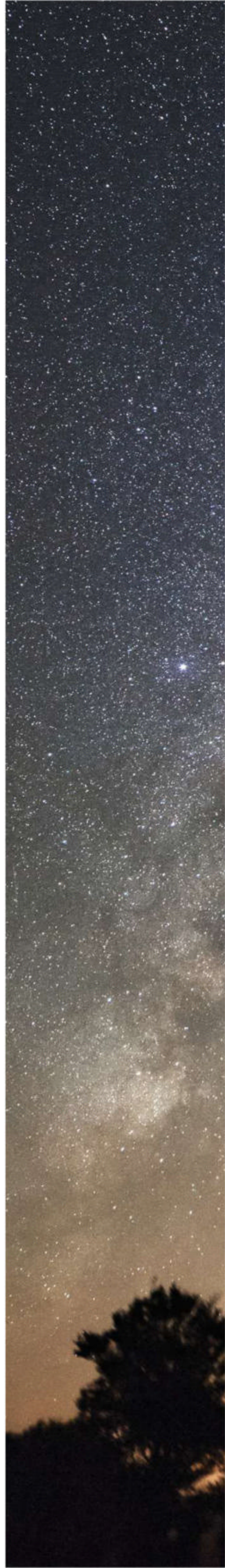
Astrophotography, of course, isn't new; if you jumped in the TARDIS and went back to the 1980s, to the heady days of the New Romantics and the first Space Shuttle launches, amateur astronomers were taking photos, but there were no digital SLRs or CCD cameras. Instead, night-sky photographers loaded up their manual SLR cameras with rolls of photographic film and then either printed out the images or had them processed as slides. Some 'push-processing' and enhancement was possible, using special chemicals or darkroom techniques, but not much.

Fast forward to today and things have moved on. With the advent of reasonably cheap entry-level digital SLR (DSLR) cameras, the incorporation of high-resolution cameras on mobile phones and the availability of advanced image-processing software, astrophotographers have the tools at their disposal that their Duran Duran-loving predecessors could only dream of.

Time for a change

You might be one of the many readers who regularly enjoys taking photos of star-trails, portraits of the constellations, images of the Milky Way, planetary conjunctions, meteor showers and displays of the Northern Lights and noctilucent clouds with your trusty DSLR mounted on a tripod. Last summer you were probably one of the countless thousands of astrophotographers around the world who photographed the naked-eye bright Comet NEOWISE, filling 1GB memory cards in one night.

But maybe you're getting restless? Are you feeling like you're taking the same photos again and again, ▸



WILL GATER, @THESHED/PHOTOSTUDIO

Broaden your horizons: this stunning 58" exposure of the Milky Way was captured using a DSLR attached to a Sky-Watcher Star Adventurer 2i Wi-Fi tracking mount

▸ over and over? Is there a nagging feeling in your stomach that you, your DSLR and its tripod have reached the end of their journey together? You want to do more. How? What do you do? Do you have to buy a more expensive camera? A bigger lens? Should you buy a telescope to fit your camera onto? Do you move to somewhere with better weather? No. The solution is surprisingly simple: get a 'star tracker'.

What exactly *is* a star tracker? There are many different models available now, for a range of prices that reflect how many fancy bells and whistles they have, how many knobs and dials they have and what garish colour they happen to be. Essentially, however, they are all the same thing – small motorised, equatorial mounts that fit on the top of a tripod and allow a camera to follow the stars (or a planet, a comet, or anything else in the sky) as they are carried across the sky by the rotation of Earth.

Why is this such a giant leap for an astrophotographer? Because your camera-and-tripod combo can only take exposures of a few seconds before that rotation causes objects in the sky to be recorded on images as trails; with a star tracker you can take exposures that are minutes instead of seconds long, with no trailing, thus producing much more detailed and colourful images.

By using a star tracker and a standard or wide-angle lens fitted to your camera you'll be able to take portraits of the constellations showing their faintest stars, not just the bright naked-eye ones, and your

▲ An image of Comet NEOWISE made from a stack of 30" exposures. These were taken with a Canon 700D DSLR with a 135mm lens, by using an iOptron SkyTracker

STUART ATKINSON, CHRIS GRIMMER, @THESHED/PHOTOSTUDIO X 3

The dark art of stacking

A guide to one of astrophotography's powerful and mysterious techniques

One of the main reasons astrophotographers buy a star tracker is to enable them to 'stack' images. Many beginners think this is too complicated to get to grips with, but all stacking means is taking lots of short exposures of the same object, then combining them to make a single image – the equivalent of a much longer single exposure. This can then be processed further to remove noise (unwanted artefacts), and bring out details and colours that can't be captured in a single image.

Stacking is primarily used for high-resolution images of deep-sky objects such as galaxies and nebulae, or to capture faint details hiding within the feathery tails of comets, but it can also be used to make stunning images of the Milky Way's frothy star clouds and constellation portraits too.

Getting started is easy. With your tracker aligned accurately, select your target, focus on it and set your camera to take multiple exposures, keeping them short to reduce trailing. Start with 20 or 30 frames. Most cameras can be set to take a sequence of 10 images, so you'll probably have to take three sets. Some stackers use an 'intervalometer' to take runs of dozens or even hundreds of images in one go, but you don't need one right away.

When taking multiple exposures you must keep checking your lens hasn't misted over; taking a hundred photos only to find out that your lens was blinded after the first 10 is not fun!

Images taken, you load them into a 'stacking program', software like RegiStax, DeepSkyStacker or Sequator. Follow the instructions; your computer will produce a single, high-resolution image. Then the hard work begins; with image-processing software you can adjust your stacked image's levels, saturation and contrast until it shows what you want it to.

▼ Multiplicity: start with a sequence of 20 or 30 frames

Choosing a star tracker

In the market for a star tracker? For starters, here's three we've reviewed

1. Sky-Watcher Star Adventurer 2i Pro Pack tracking mount

£375

A stable star tracker with a good weight capacity, plus Wi-Fi and app control.

bit.ly/sky-watcher-staradventurer

2. Bresser StarTracker Astronomical Photo Mount Kit

£481

A compact star-tracker platform with a tripod for wide-field photos of the night sky.

bit.ly/bresser-startracker

3. Omegon Mini Track LX2 tracking mount set

£139

An innovative, fully mechanical star tracker which has no need for batteries.

bit.ly/omegon-minitrackLX2

Milky Way photos will show details and features in its star clouds and dust lanes not obvious to the naked eye. With a longer lens, you'll be able to take beautifully detailed, close up images of comets and deep-sky objects such as galaxies, nebulae and star clusters, too.

But perhaps the main benefit of a star tracker is that it will allow you to take multiple, identical images of the same object, which you can then sandwich or integrate together in free image-processing software to make a single image with incredible resolution and detail – a sorcerous process called 'stacking'. This can be done with short exposures on a 'static' DSLR too, but much better results are achieved with longer, 'tracked' exposures.

Choosing a star tracker

So which star tracker should you buy? We've provided a guide to some of the most popular models currently available (above), but make sure you do some research and choose one that fits your needs and budget, bearing in mind they all basically do the same job.

Whichever tracker you buy you'll need a tripod to mount it on, and this might mean some extra expense because the light, clickety tripod you've been using with your DSLR until now will almost certainly not be sturdy enough to support the weight of a tracker. If the cost of a brand new heavy tripod is prohibitive, try looking for a secondhand one.

Before you've even screwed your tracker onto its tripod there's some work to do. Start by fitting your standard 50mm lens to your camera – don't reach for your longest zoom lens right away. Next, fit a cable release to your camera, to avoid vibrations when beginning your exposures. Make sure there's plenty of room on your camera's memory card – you'll be amazed how quickly it will fill up once you start taking photos, especially if you're taking multiple images to stack later – and make sure your camera's battery is full too. Always have at least one spare; taking dozens or even hundreds of images during a tracking session will drain your battery quickly.

With your camera prepared and fitted to your tracker it's time to mount the tracker on its tripod. ▸

Setting up a star tracker

A quick step-by-step guide to getting your star tracker up and running

STEP 1

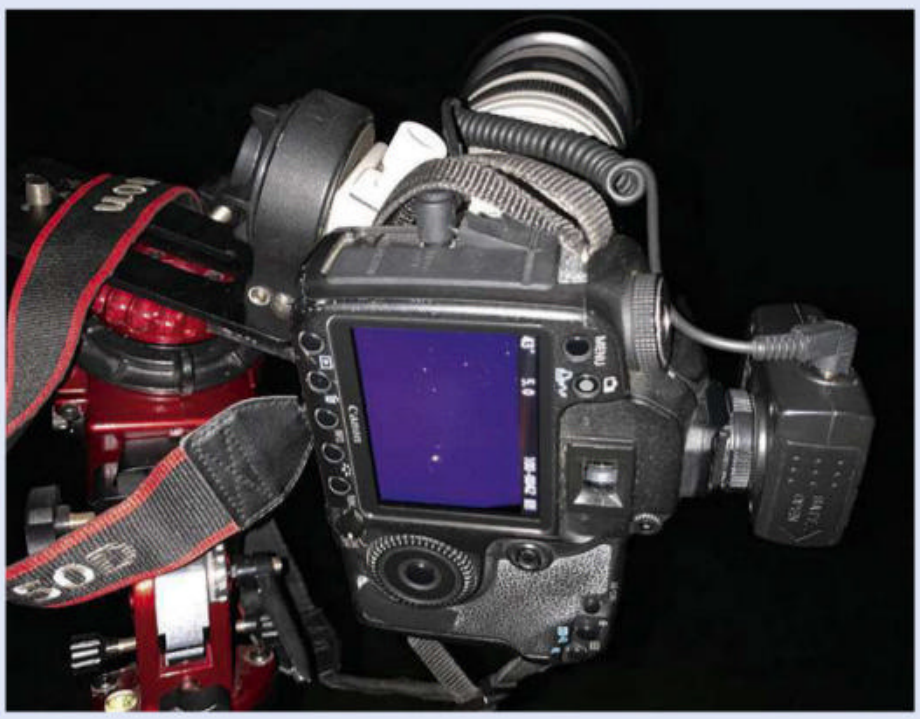
Mount your tracker on a sturdy tripod that's able to hold its weight without sagging, then level it and set it to your latitude. Make sure everything is tightened up with no slippage.

STEP 2

Using its finderscope or device, align the tracker on the Pole Star. You can use a phone app to help you polar align even more accurately, which will give sharper images.

STEP 3

With your target selected and focused sharply, set your camera to take a sequence of images and begin the exposures using a cable release to reduce vibrations.

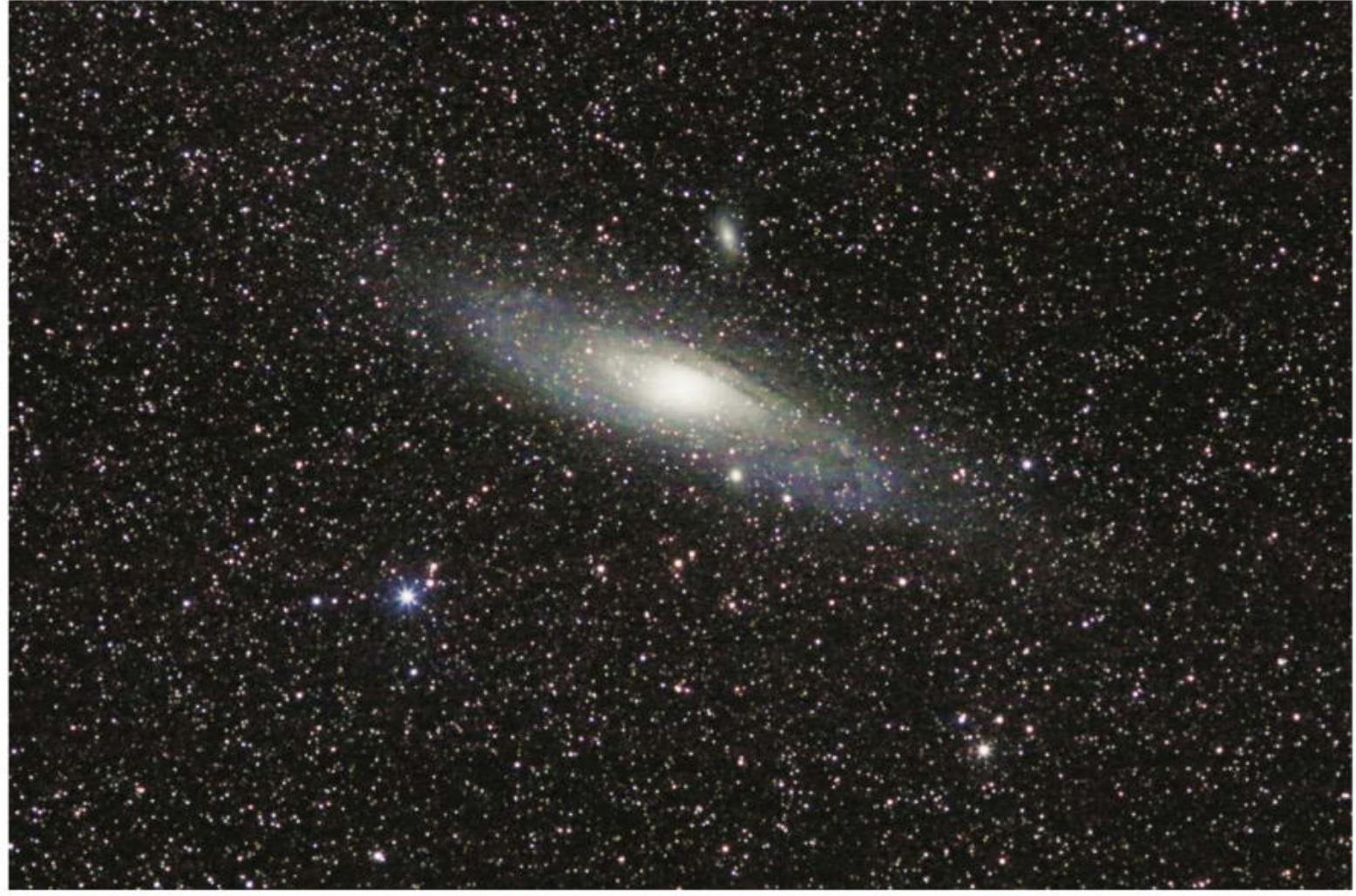


STEP 4

Review your images – if any are trailed check your tracker is level and aligned properly. Keep checking your camera lens has not misted over in between exposures too.

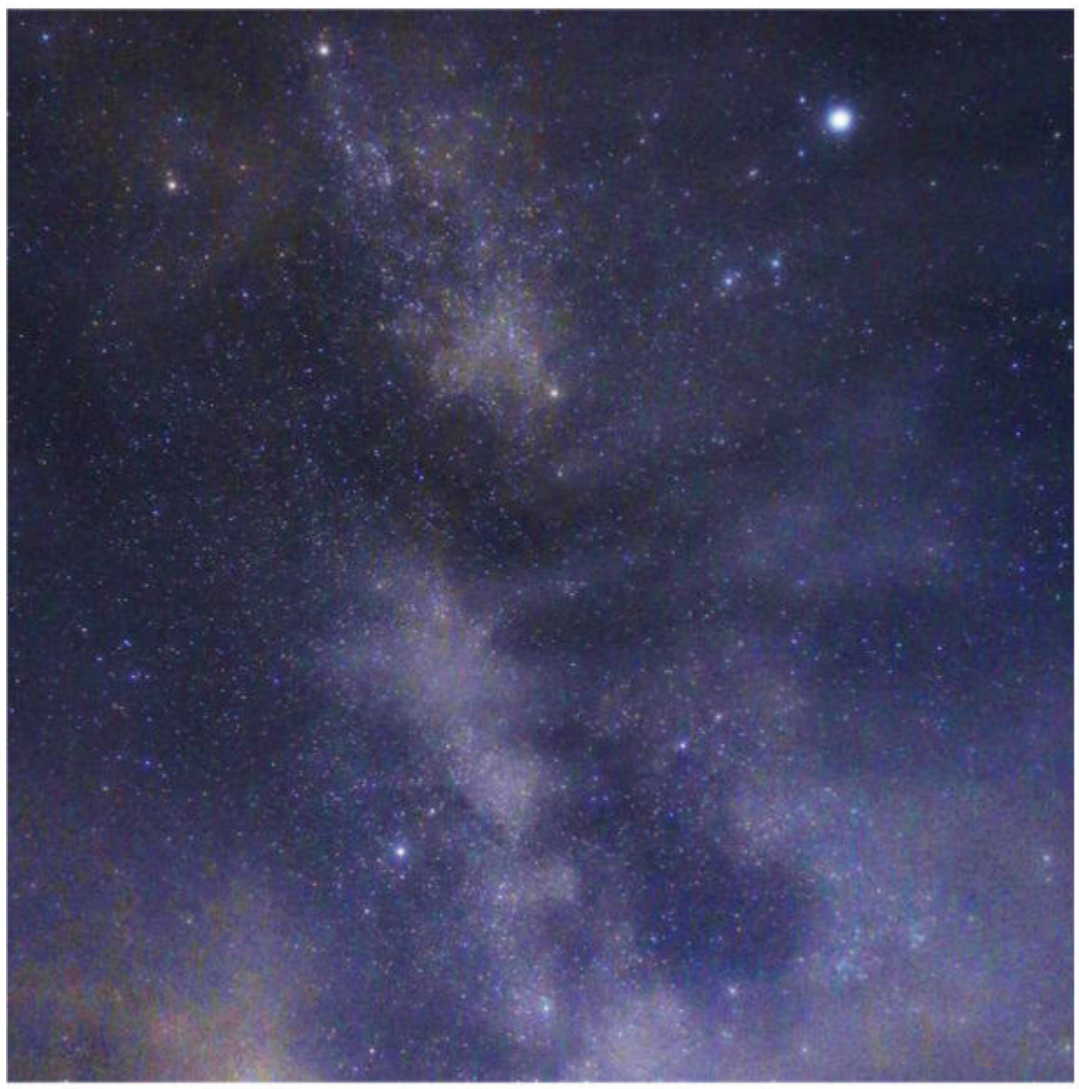
▸ Make sure it is level and that all the legs are fully extended and then set it up on as even a surface as you can find. Once you have your tracker on its tripod and your camera fitted to it, there's still a little bit more work to do before you can start taking photos. First, you have to set the tracker to your latitude, usually using a knob or a wheel to adjust its angle of tilt, and then you have to align it with the Pole Star as accurately as possible; the more accurate this 'polar alignment', the better your images will be – it really is as simple as that. Most trackers have a small finderscope – or at least a 'peep hole' – you use to line them up with the Pole Star, which will give you an alignment that's good enough for taking images, but you can now use various phone apps to help you achieve much more accurate alignment.

Once your tracker is aligned it's very important to make sure everything is tightened up properly; any



► Galactic details: an image of the Andromeda Galaxy, M31 – taken using an iOptron SkyTracker and Canon 700D DSLR with a 135mm lens – made from a stack of 20x 30" exposures...

▼ ...and the Milky Way, taken with the same setup as above, this time with an 18–55mm lens set at 18mm, using a stack of just three exposures



Stuart Atkinson is a lifelong amateur astronomer and author of 11 books. He enjoys processing raw Mars mission images to create colour panoramas

loose knobs etc will mean the tracker will slip during your long exposures, resulting in exactly what you wanted to avoid – trailed images.

Taking test shots

With all that done you can finally start taking images! Set the lens aperture wide and the ISO number (what we used to call 'film speed' and many of us still do), and focus on your chosen subject as sharply as you can, using your camera's 'Live View' feature if it has one. Finally, set the exposure time, just for half a dozen seconds or so for your first test shot so you can quickly see if everything is set up properly. Begin the exposure by clicking your cable release... and wait. If the stars on your test image are trailed then something is loose or you are not polar-aligned accurately enough – or you haven't turned the tracker on, an easy mistake!

Once you have taken a short exposure that shows everything clear and sharp it's time to allow yourself an expectant smile, and see what your new tracker can do.

Keeping the same ISO, set your next exposure for longer, say 20 seconds or so. When you look at the image on the back of your camera you'll be amazed how many more stars there are on it than on your short-exposure test shot – and, like that ape at the start of *2001: A Space Odyssey* who realises that he can use a bone as a club, you'll have a wide-eyed "Oh wow...!" moment as you discover just how much more you'll be able to do with your camera now.

But having a tracker doesn't mean you can suddenly start taking hour-long exposures like you've got your very own Hubble Space Telescope. You'll still have to keep exposures quite short to avoid inaccuracies with tracking. If you have everything tightened up and aligned properly then, in my experience, a 50mm lens can comfortably take 120-second exposures, a 135mm lens 60-second exposures, a 300mm lens 30-second exposures and wide-angle lenses up to two or even 2½-minute long exposures before some trailing is evident. Having said that I've managed almost four minutes with my favourite 135mm lens, but only when everything was set up absolutely perfectly.

Whichever lens you use it's important you keep checking your images after taking them. It's easy to assume everything is working perfectly as your camera clicks away on your whirring tracker, and tempting to check your phone or even walk away from the camera and just let it do its thing, but trust me, if you're not paying attention during a photo session your lens can lose focus or become dewed-over, your tracker's polar alignment can slip or, worst of all, its batteries can fail and you'll find you've just spent two hours taking star trails instead of pin-sharp tracked images (and yes, I've done that...). So make sure you check everything.

By adding a star tracker to your astrophotography arsenal you'll be able to take images far beyond the ability of just a DSLR on a tripod. It's like having a whole new night sky to photograph, and you'll soon be taking images of feathery comet tails, the constellations and the star-frothed Milky Way to be proud of.

PAUL MONEY X 4, STUART ATKINSON X 2

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OSTARA

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All surfaces are fully multicoated further enhancing brightness and clarity.
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OPTICAL HARDWARE

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For more information and to find your nearest stockists, please visit www.opticalhardware.co.uk/stockists
All offers are subject to availability, prices and specifications are subject to change without notice. E&O.E. Your statutory rights are not affected.

16-PAGE CENTRE PULLOUT

BBC Sky at Night MAGAZINE

The Sky Guide

APRIL 2021

A MONTH WITH THE MOON

View a waxing crescent Moon, an occultation of M35 and a clair-obscur effect like the Loch Ness Monster

EVENING ENCOUNTER

As it re-emerges in twilight skies, Venus is joined by Mercury

APRIL SHOWER

Spot the peak of the Lyrid meteor shower

PETE LAWRENCE

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four

Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

- A full Moon appears close to perigee
- Jupiter's Galilean moons cast shadows
- Asteroid 9 Metis reaches opposition

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

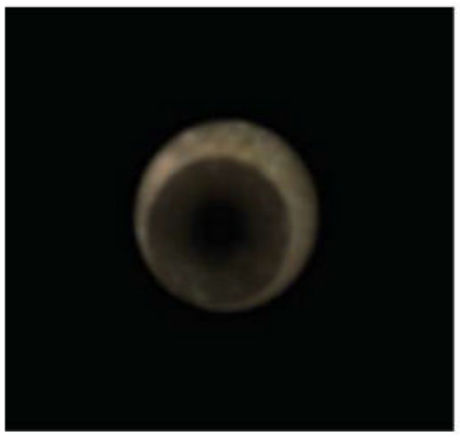
For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

APRIL HIGHLIGHTS

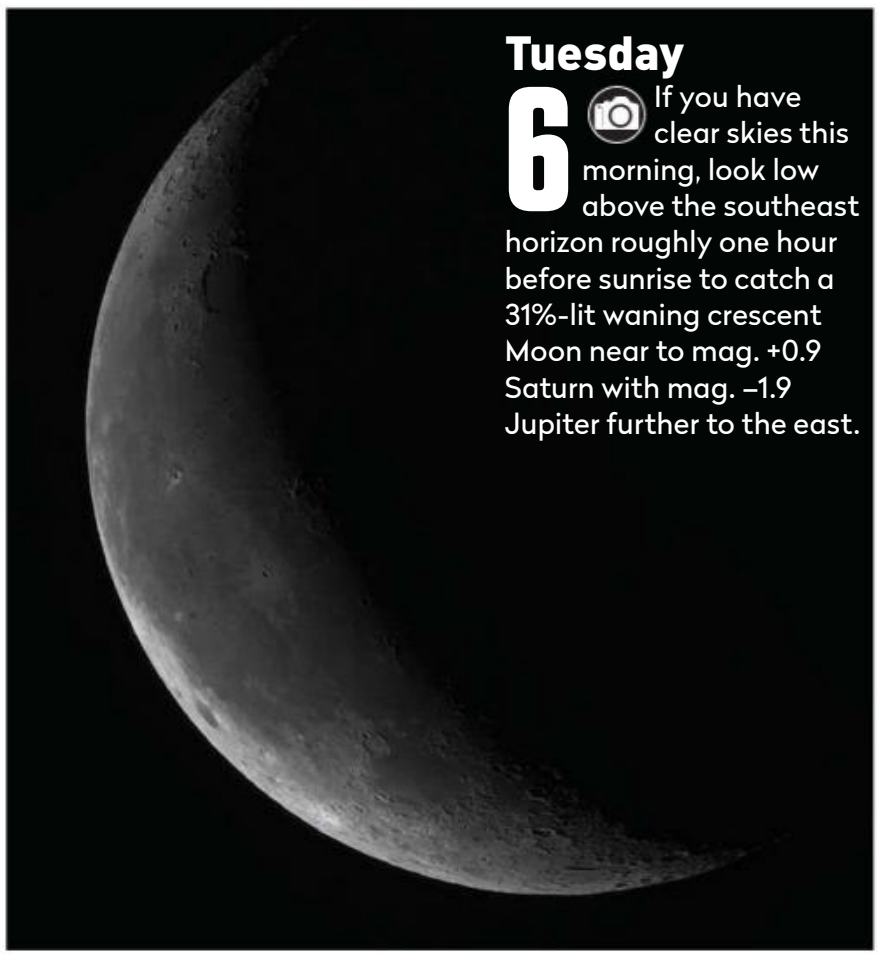
Your guide to the night sky this month

Friday
2 This morning's 75%-lit waning gibbous Moon sits 4.5° from mag. +1.0 Antares (Alpha (α) Scorpii). Catch them shortly after they rise low in the southeast around 02:00 BST (01:00 UT).

Sunday
4 Asteroid 9 Metis reaches opposition in the constellation of Virgo today. Find out more about Metis on page 53.

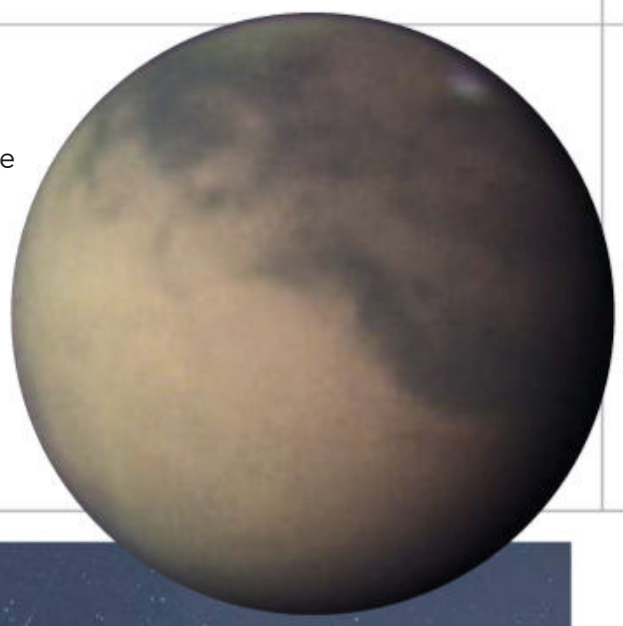


◀ Monday
12 A very tricky observation occurs in the early hours. Between 05:22 and 05:36 BST (04:22–04:36 UT), Io's shadow will cross the face of the outer Galilean moon Callisto. Jupiter's altitude is just 3.5° above the east-southeast horizon at this time!

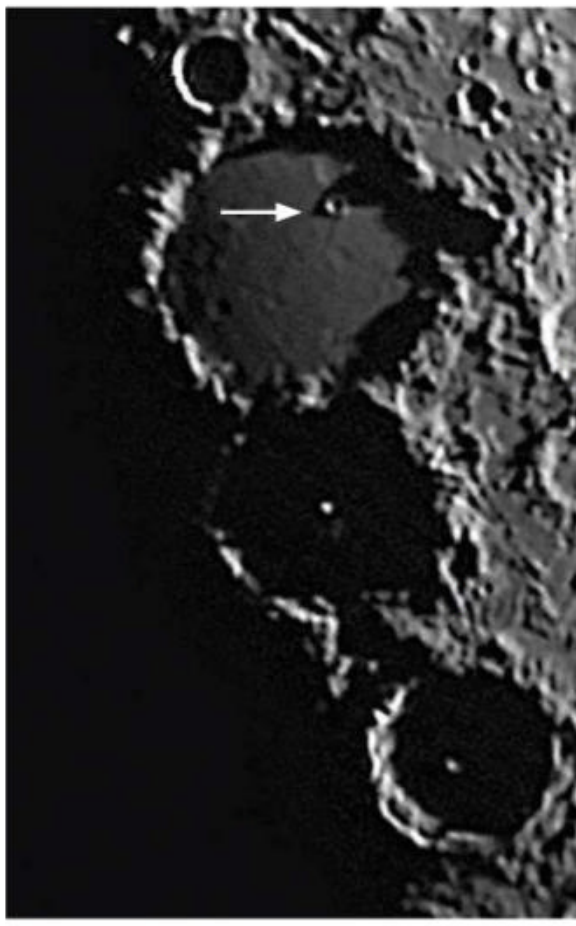


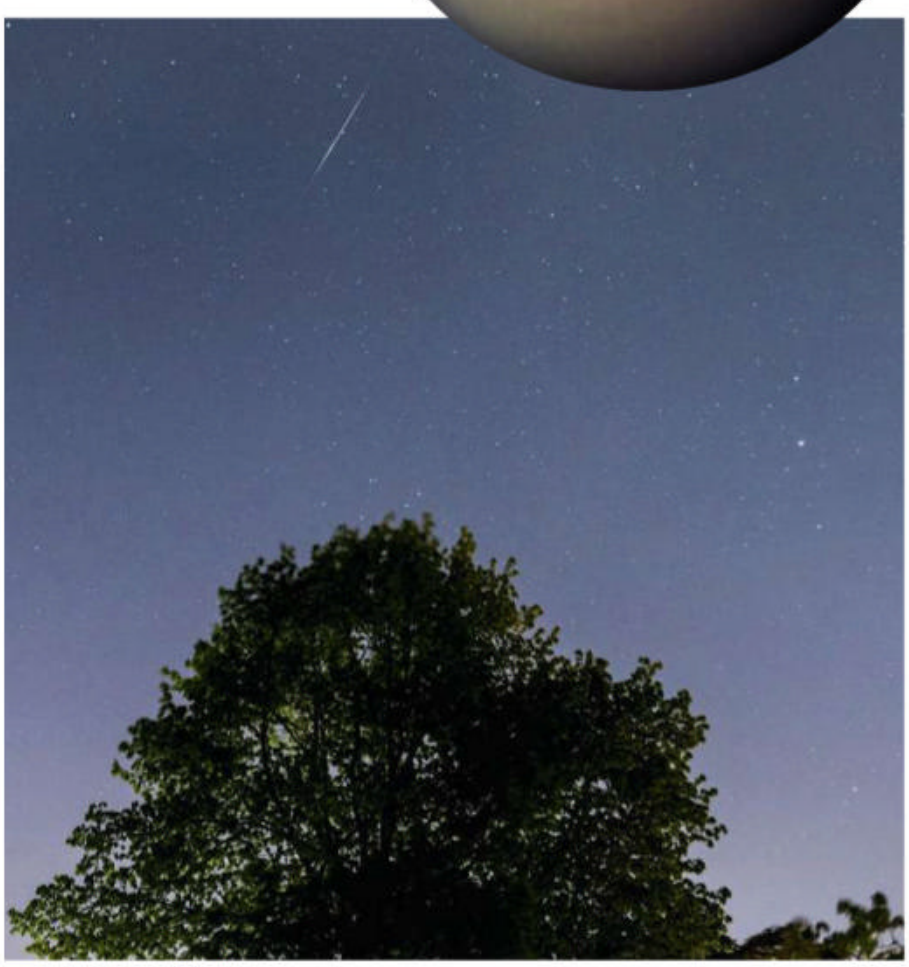
Tuesday
6 If you have clear skies this morning, look low above the southeast horizon roughly one hour before sunrise to catch a 31%-lit waning crescent Moon near to mag. +0.9 Saturn with mag. –1.9 Jupiter further to the east.

Saturday ▶
17 As the sky darkens, the 24%-lit waxing crescent Moon sits 3.9° to the east of mag. +1.5 Mars.



Sunday
18 Starting at 01:15 BST (00:15 UT), a 27%-lit waxing Moon begins to occult the mag. +5.5 open cluster M35 in Gemini. Much of the cluster is hidden by the Moon, but the event continues past the point where both objects set.





◀ Thursday
22 The peak of the Lyrid meteor shower is in daylight at 14:00 BST (13:00 UT). Despite a bright Moon it will be best observed on the nights of 21/22 and 22/23 April.

See the Moon's 'Jewelled Handle' clair-obscur effect this morning.

Monday
26 This evening, mag. +1.5 Mars lies 1.6° north of open cluster M35 in Gemini.

PETE LAWRENCE X 5, STEVE MARSH, STEPHEN CHUNG/ALAMY LIVE NEWS

Wednesday ▶ 7

This morning it's the turn of mag. –1.9 Jupiter to get a visit from the Moon. The 22%-lit waning lunar crescent lies 5.5° below the planet and is visible low in the southeast, approximately 40 minutes before sunrise.

Tuesday 13

This evening, look out for a beautiful 2%-lit waxing crescent Moon low in the west shortly after sunset. As time goes on and the sky darkens, the Moon should start to show its night side, gently glowing by the reflected light of Earth.

Wednesday 14

Waxing crescent Moons are well positioned at this time of year, as this evening's example demonstrates. Catch the slender 6%-lit waxing crescent above the west-northwest horizon as the evening twilight darkens.

Thursday 15

This evening the thickening waxing lunar crescent, now 12%-lit, sits between the Hyades and Pleiades open clusters. Catch the show over the west-northwest horizon as the sky darkens.

◀ Monday 19

This evening around 22:30 BST (21:30 UT) the head and neck of Nessie forms on the Moon, as the Sun rises over the crater Ptolemaeus. It's caused by sunlight casting shadows of Ptolemaeus's rim and the 8km-crater Ammonius.

Tuesday 20

The clair-obscur effect known as the 'Eyes of Clavius' can be seen on this evening's Moon around 22:20 BST (21:20 UT). It occurs when sunlight illuminates the tallest craterlet rims within the crater Clavius in the southern part of the Moon.

Friday 23

Can you spot a bright star-like glow near lunar crater Aristarchus late this evening? If so, you've just seen the clair-obscur effect known as the 'Star-tip Mountain'.

Sunday 25

If you have a flat west-northwest horizon you might be able to spot mag. –1.5 Mercury just over a degree from mag. –3.8 Venus this evening. Despite their brightness, this will be challenging as both planets set 40 minutes after the Sun.

◀ Tuesday 27

April's full Moon occurs in the early hours around 12 hours ahead of perigee. It will appear slightly larger and brighter than an average full Moon and is what some call a 'Supermoon'. See page 72 for more on Supermoons.

Family stargazing

With the Moon well positioned in the evening sky from 13 April, this is a great time to introduce youngsters to its many wonders. One excellent way to get to know the Moon is to use a pen and paper and draw what can be seen with the naked eye. Concentrate on the shape and how it changes from one night to the next. Try and record the darker patches on its surface – the lunar seas. Explain that, despite their watery name, they are vast expanses of solidified lava. Keep the interest going by looking at some of the other lunar events happening this month on page 46. **www.bbc.co.uk/cbeebies/shows/stargazing**

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

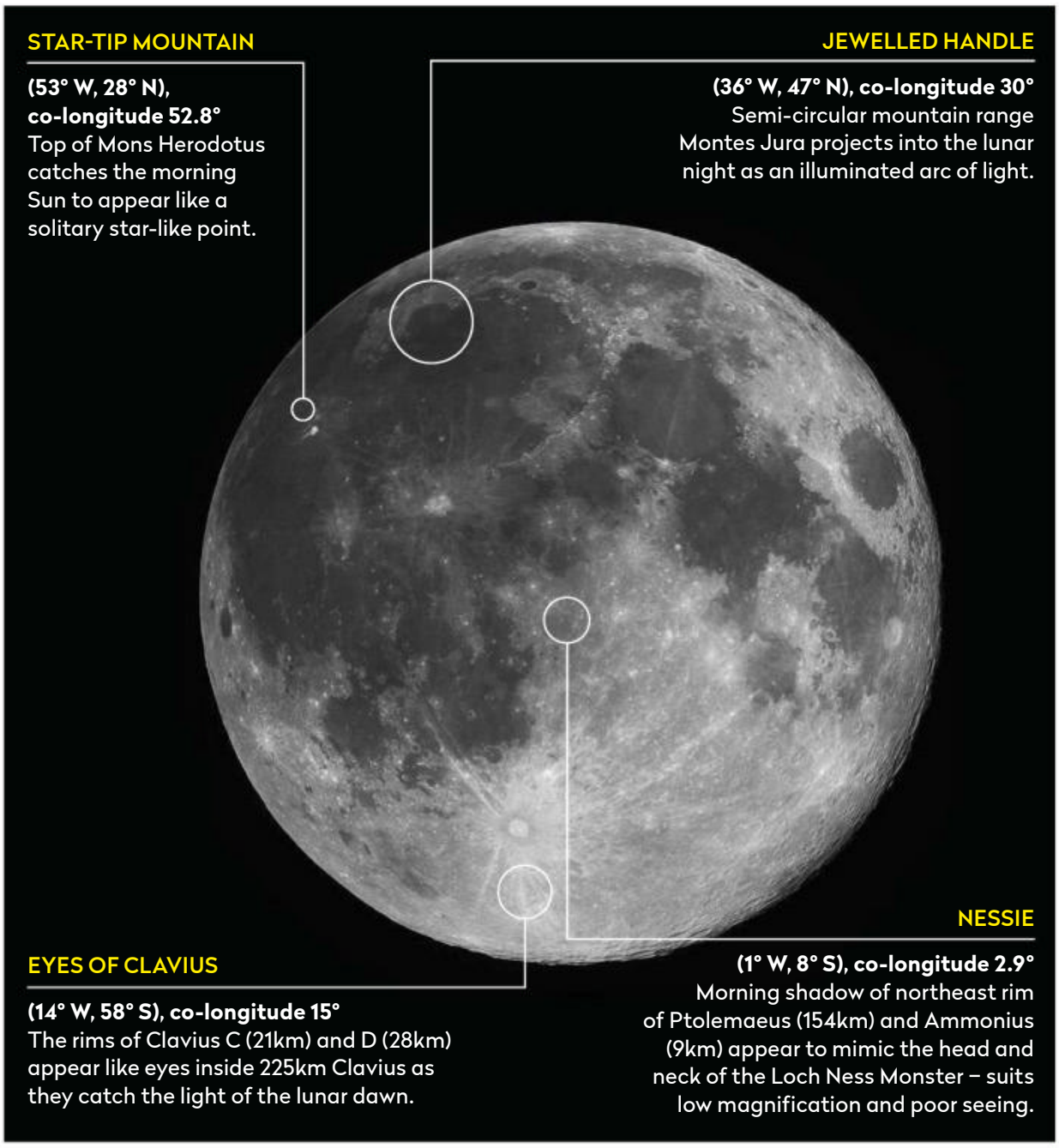
Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

THE BIG THREE

The three top sights to observe or image this month



◄ Tricks of the light: look out for this month's clair-obscur effects, caused by sunlight on the Moon's surface

DON'T MISS

THE SPRING MOON

BEST TIME TO SEE:
6–7, 13–15, 17–20, 22–23 and 27 April

The spring months offer excellent opportunities for observing the early waxing phases of the Moon. Optimally positioned, these waxing crescents are irresistible if you have a telescope.

We'll start with a couple of early morning conjunctions. Although the Moon isn't well placed in the morning sky, you can spot the 31%-lit waning crescent near Saturn on 6 April. On the following morning, the 7th, a 22%-lit waning crescent Moon sits near Jupiter. Look for the meeting with Saturn one hour before sunrise low above the southeast horizon, and 40 minutes before sunrise for Jupiter in the same direction.

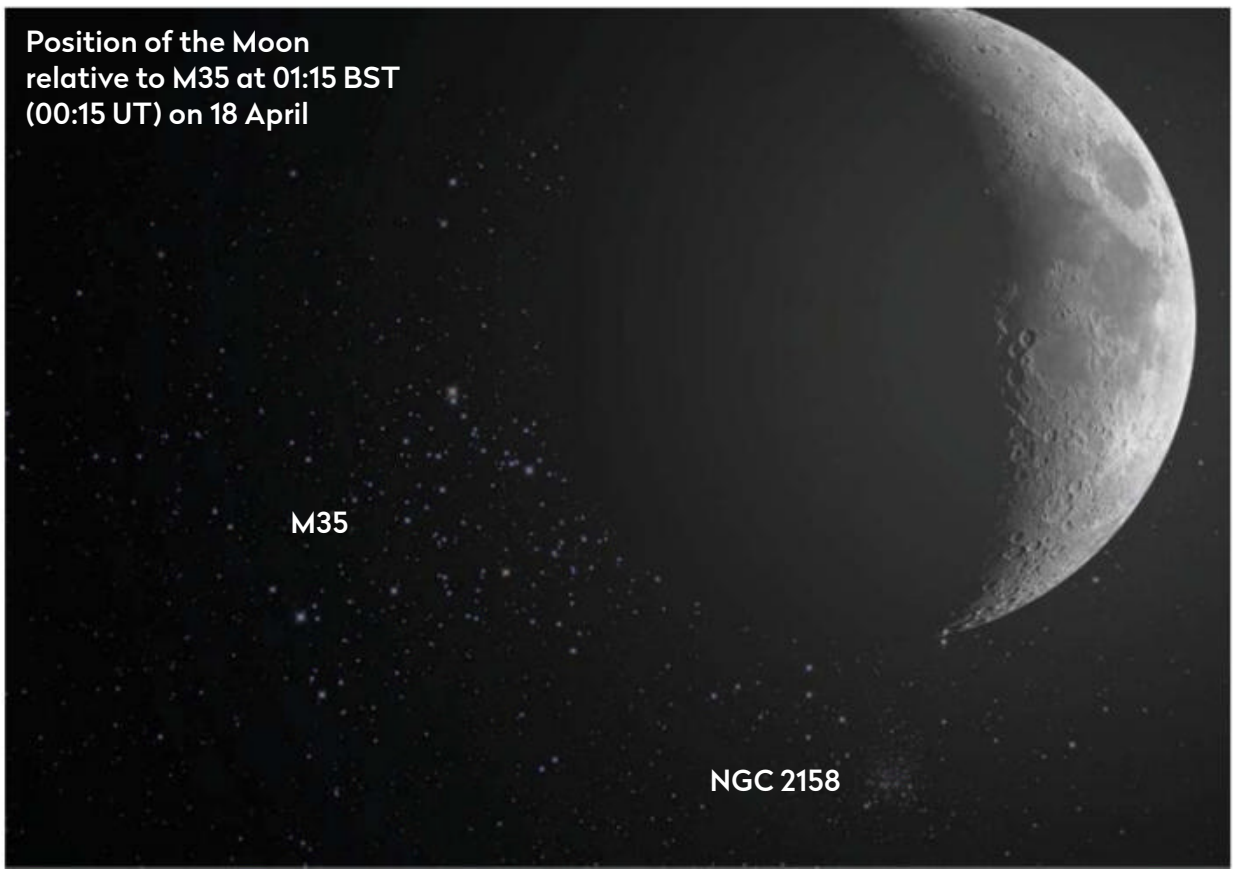
The Moon is new on 12 April, thereafter re-emerging into the evening twilight. On the 13th, a 2%-lit waxing crescent appears low in the west after sunset, and again on the 14th as a 6%-lit crescent low above the west-northwest horizon. On the 15th the now 12%-lit waxing crescent sits between the Hyades and Pleiades open clusters, a perfect alignment for a photo opportunity.

After an encounter with Mars on the 17th, starting around 01:15 BST (00:15 UT) on the 18th, the 27%-lit waxing crescent Moon begins to occult the mag. +5.5 open cluster M35 in Gemini. The occultation will still be underway as the Moon sets.

On 19 April, it's the turn of 'Nessie' to make an appearance! This odd clair-obscur effect occurs as the Sun rises over the crater Ptolemaeus. As sunlight catches the crater's rim and an internal 8km crater called Ammonius, it causes a shadow like the Loch Ness Monster to appear.

On the evening of 20 April, sunlight pouring into crater Clavius illuminates the elevated rims of two internal craters causing them to appear like eyes in the dark, a clair-obscur effect known as the 'Eyes of Clavius'. Then on the morning of the 22nd, the peaks of the Jura mountains bordering the Sinus Iridum will form another clair-obscur effect known as the 'Jewelled Handle'. A less well-known effect occurs on the evening of the 23rd when a bright star-like point near crater Aristarchus creates the 'Star-tip Mountain'.

The full Moon on 27 April occurs in the early hours, 12 hours ahead of perigee; the point in the Moon's orbit where it's closest to Earth. This perigee full Moon appears a little brighter and larger than an average full Moon, and is known as a 'Supermoon'.



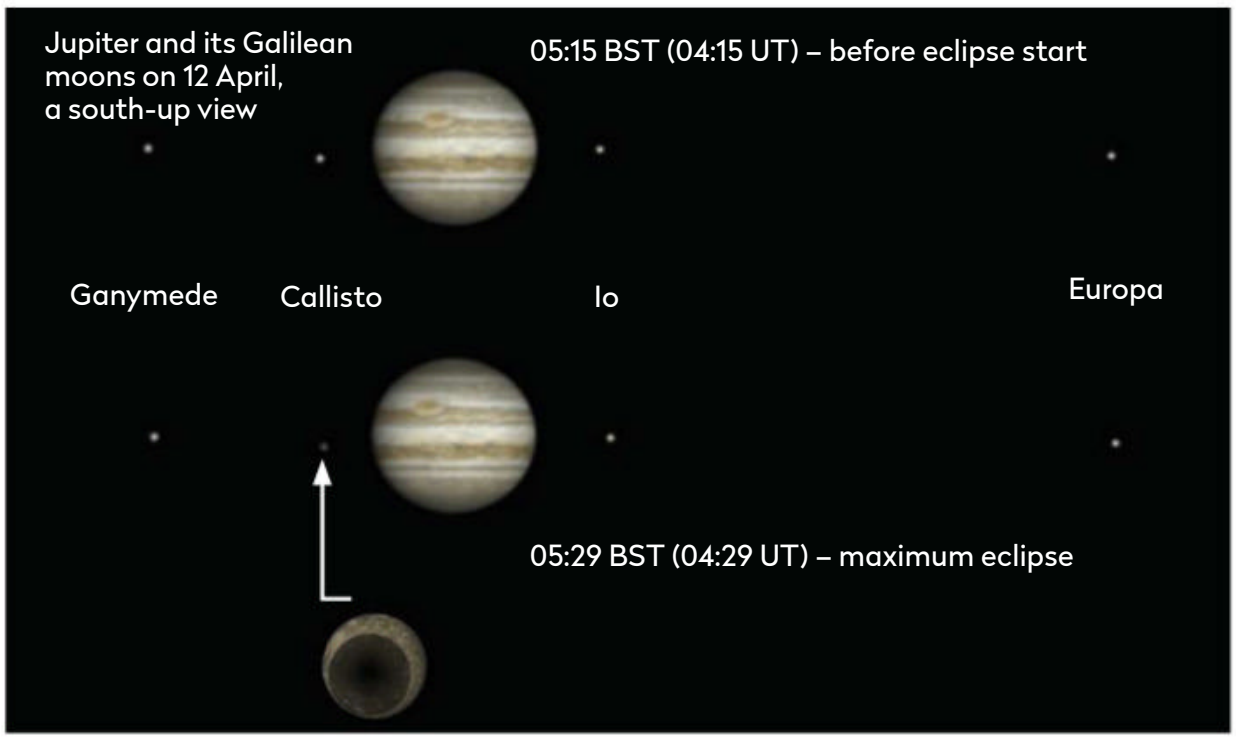
Position of the Moon relative to M35 at 01:15 BST (00:15 UT) on 18 April

ALL PICTURES: PETE LAWRENCE

Galilean moon shadows

BEST TIME TO SEE: 12 April, from 05:15 BST to 05:40 BST (04:15 UT to 04:40 UT)

▼ **Observe Io's shadow as it crosses the face of Callisto on 12 April**



Jupiter experiences an equinox at the start of May. If you were on the planet, the Sun would appear on Jupiter's equivalent to the celestial equator, the projection of its equatorial plane into the gas giant's sky. When this occurs on Earth, it marks the transition from winter to spring, or summer to autumn, and the same is true on Jupiter. However, while Earth's axial tilt of 23.4° creates marked seasonal effects on our planet, this is less so for Jupiter, which has a tilt of just 3.1°.

One major visual effect that does occur involves the planet's four largest Galilean moons. Their orbits are only slightly tilted to Jupiter's equatorial plane, and around the time of a Jovian equinox the Sun and Earth effectively see their orbits edge on.

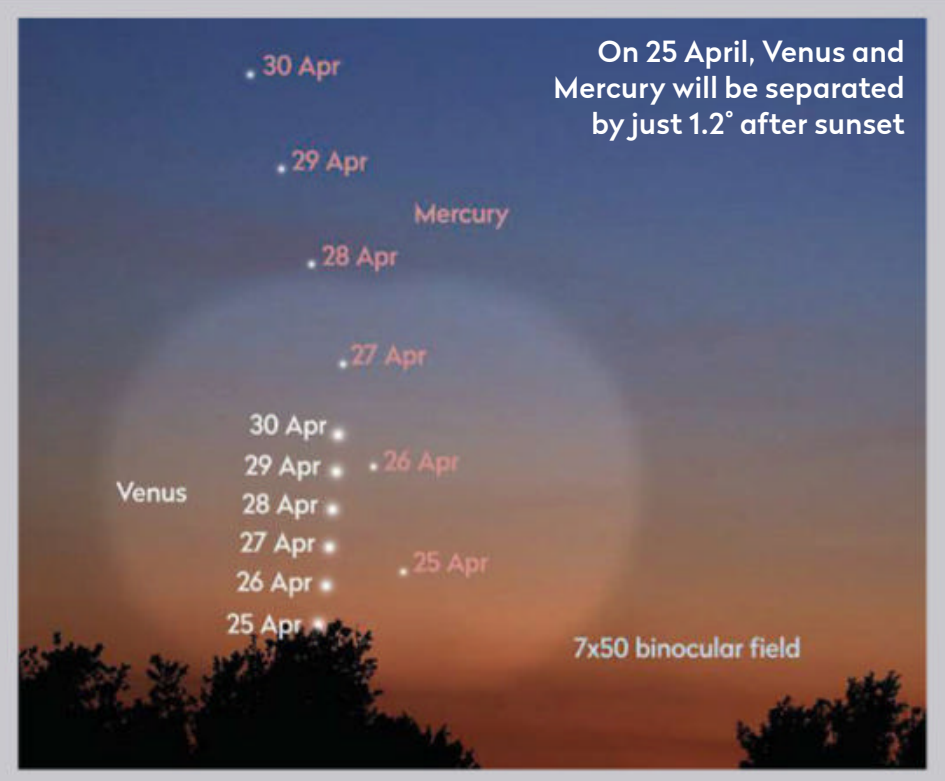
This means that the Galilean moons can appear to interact with one another, passing in front of, or casting their shadows on each other's discs. These occurrences are collectively known as 'mutual events'. We're quite early in the UK's Jupiter season, so any mutual events currently need to be very well timed to be observable.

Almost falling into this category, on 12 April, Io's shadow crosses the face of Callisto between 05:22 BST and 05:36 BST (04:22 UT to 04:36 UT). Jupiter's altitude will be just 3.5° above the east-southeast horizon at this time, so pretty low. If you can get a view of the planet, what you'll see will be Callisto's disc appearing to dim as Io's shadow passes across it. The eclipse should be observable through small instruments.

As we head further into 2021 there will be further events to see. However, Jupiter's low altitude does somewhat limit the window of opportunity for many of them. We'll do our best to update you on as many as we can over the coming months.

Mercury-Venus conjunction

BEST TIME TO SEE: 25–30 April



Mercury and Venus have a close encounter this month. Venus was in superior conjunction on 25 March and is now emerging into the evening sky. Its separation from the Sun isn't great in April, but the steep angle the ecliptic plane makes with the western horizon at sunset during spring helps keep Venus above the horizon after sunset.

On 25 April, Venus and Mercury appear separated by just 1.2° after the Sun has set. They remain above the west-northwest horizon for around 45 minutes after the Sun. Venus will be shining at mag. –3.8, Mercury at mag. –1.5, both capable of punching through the bright twilight sky. We'd recommend waiting for the Sun to properly set, then using binoculars to first locate Venus. It shouldn't be long before Mercury too pops out of the bright twilight sky.

While Venus takes a while to crawl away from the Sun, Mercury appears to move much faster and over the following nights the Solar System's innermost planet zips away from Venus, climbing higher in the sky. It retains a decent brightness too, staying brighter than mag. –1.0 for the rest of the month. It's a great opportunity to try and spot Mercury if you've never seen it before.

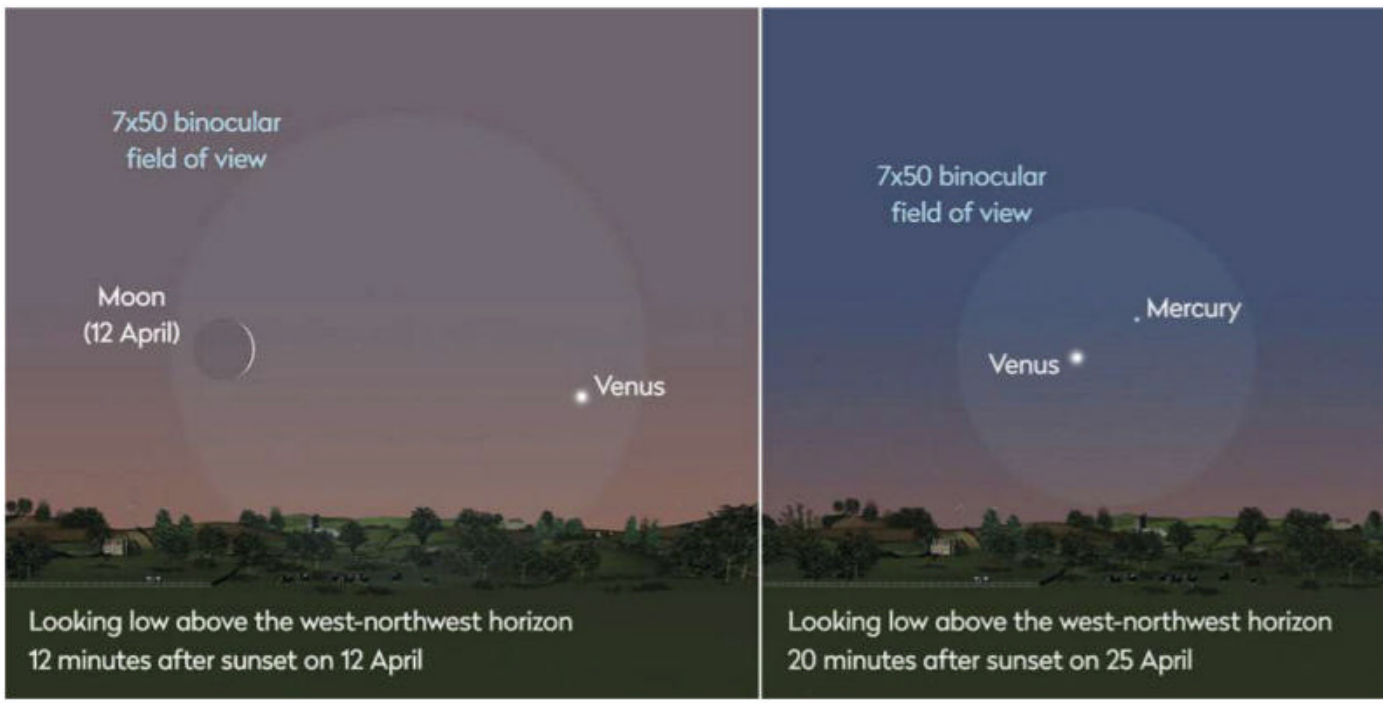
THE PLANETS

Our celestial neighbourhood in April

PICK OF THE MONTH

Venus

Best time to see: 30 April, from 20 minutes after sunset
Altitude: 3.5° (very low)
Location: Aries
Direction: West-northwest
Features: Phase, subtle cloud shadings
Recommended equipment: Binoculars



▲ **Use binoculars to catch Venus with the Moon on 12 April, and with Mercury on 25 April**

Venus slowly re-emerges into the evening twilight during April, but being on the far side of its orbit from Earth, slow is indeed the word! On 12 April, it sits 3.7° northwest of a less than 1%-lit thin Moon which, at just 7.8° from the Sun, itself may be a tricky spot. Things improve as we head towards the end of April, Venus's brightness helping the planet stand out so that it can confidently be seen against the evening twilight. Currently Venus shines at mag. –3.8.

On 25 April, Venus lies 1.1° south of mag. –1.5 Mercury, Venus setting 40 minutes after the Sun on this date. By the time the end of the month arrives, Venus sets 50 minutes after the Sun.

We had a spectacular evening apparition of Venus in 2020 when the planet was able to reach a high altitude and it was well separated from the Sun. This year's appearance won't be so favourable, the timing keeping Venus rather low to the horizon as it separates from the Sun. Despite this, there are still many things to look forward to.

Meetings of Venus and the waxing crescent Moon are an amazing sight to behold, and 2021 presents numerous opportunities to see these. Although the meeting of the pair on 12 April may be tricky to catch, the one on 13 May will be a little easier. The evenings of 11 and 12 June will present a fabulous opportunity to see the thin lunar crescent near Venus, dates which repeat in July.

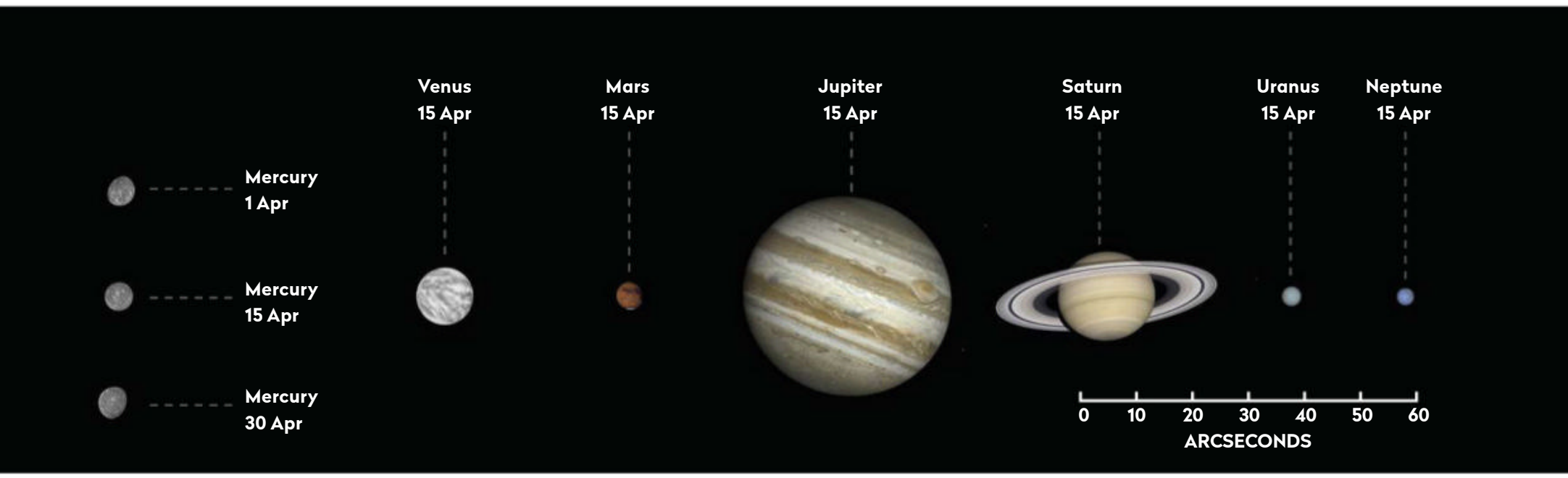
▲ **Venus will slowly re-emerge into the evening twilight during April**

Things start getting tricky as we head into August, as Venus will be slipping further south in the sky and its time above the horizon after sunset will be short. A lovely, albeit low, meeting between the thin waxing crescent Moon and Venus occurs on the evenings of 10 and 11 August, repeated on 9 and 10 September.

PETE LAWRENCE X 3

The planets in April

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



Mercury

Best time to see: 30 April, from 30 minutes after sunset
Altitude: 6° (low)
Location: Aries
Direction: West-northwest

April starts with Mercury in a poor position in the morning sky. Edging closer towards the Sun, Mercury reaches superior conjunction on 19 April, marking its transition from a morning to an evening planet. Fortunately, things improve greatly for its evening appearance, Mercury rapidly increasing in elevation after sunset towards April's end. On the 25th, the mag. –1.5 planet sits 1.2° north-northwest of mag. –3.8 Venus. Both planets remain close for the rest of April. On the 30th, Mercury shines at mag. –1.1 and sets 85 minutes after the Sun.

Mars

Best time to see: 1 April, 21:00 BST (20:00 UT)
Altitude: 42°
Location: Taurus
Direction: West

Mars is now well past its best for the current apparition, with its brightness dropping from mag. +1.3 to mag. +1.5 over the month and its apparent size dropping from and 5.3 to 4.7 arcseconds. It's also getting lower as darkness falls; its rapid apparent eastward motion will keep it visible for a while longer but with such a small apparent disc size it'll be tricky to get any serious detail from the planet via a scope.

A 26%-lit waxing crescent Moon sits 3.5° east of Mars on 17 April. On the 26th and 27th, Mars lies 0.5° north of the open cluster M35 in Gemini.

Jupiter

Best time to see: 30 April, from 04:30 BST (03:30 UT)
Altitude: 5° (very low)
Location: Aquarius
Direction: East-southeast

Jupiter is a morning planet, rising 70 minutes before the Sun at the month's start, but it's poorly placed so it doesn't achieve much of an altitude. A 22%-lit waning crescent Moon sits 5.7° south of Jupiter on the morning of 7 April. At the month's end, Jupiter still rises 70 minutes before the Sun, reaching a peak altitude of 14° before sunrise. Next month, Jupiter has an equinox.

Although the planet's small axial tilt of 3.1° doesn't cause dramatic seasonal variations in its atmosphere, around an equinox we do get to see some interesting mutual events between the four Galilean satellites. See page 47 for more on these.

Saturn

Best time to see: 30 April, from 04:00 BST (03:00 UT)
Altitude: 5° (low)
Location: Capricornus
Direction: Southeast

Saturn is a morning object, distancing itself from the Sun. It sits in the constellation of Capricornus, appearing like a mag. +0.7 yellowish star. A 31%-lit waning crescent Moon sits beneath it on the morning of the 6th, with Jupiter 12° to the east-northeast. At April's end, Saturn manages to attain an altitude of around 13° before it's lost in dawn twilight.

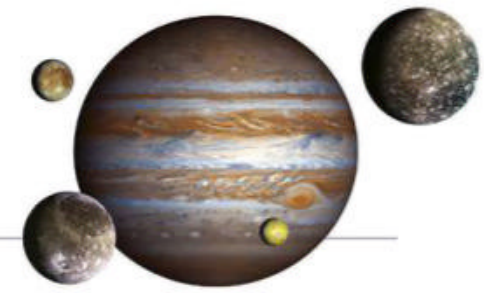
Uranus

Uranus is not visible this month, which is a pity as on 23 April it sits between mag. –3.8 Venus and mag. –1.7 Mercury. Uranus is in conjunction with the Sun on 30 April.

Neptune

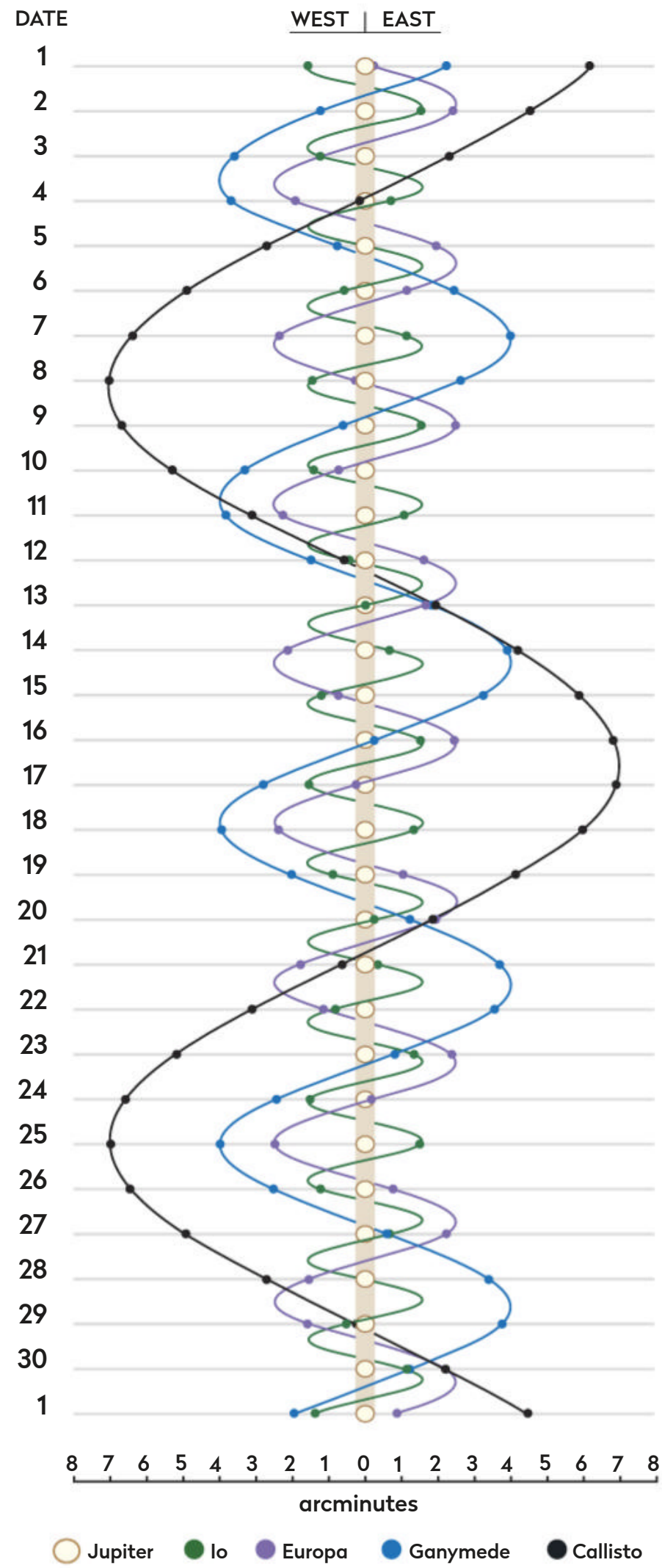
Not visible this month.

More ONLINE
Print out observing forms for recording planetary events



JUPITER'S MOONS: APRIL

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



THE NIGHT SKY – APRIL

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Circlet — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER
- COMPASS AND FIELD OF VIEW
- MILKY WAY

When to use this chart

1 April at 01:00 BST
15 April at 00:00 BST
30 April at 23:00 BST

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in April*

Date	Sunrise	Sunset
1 Apr 2021	06:43 BST	19:46 BST
11 Apr 2021	06:19 BST	20:04 BST
21 Apr 2021	05:57 BST	20:22 BST
1 May 2021	05:35 BST	20:40 BST

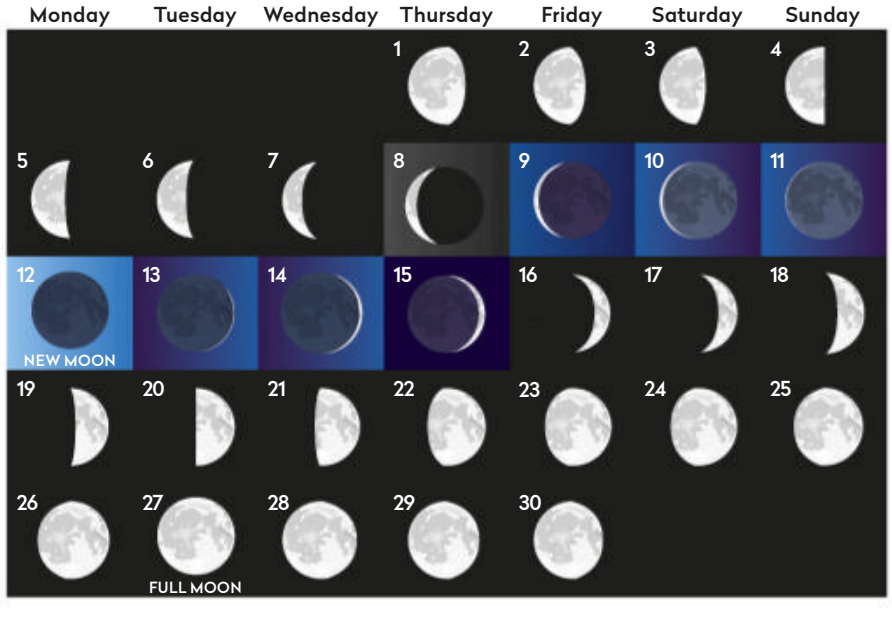
Moonrise in April*

Moonrise times

1 Apr 2021, --:-- BST	17 Apr 2021, 08:31 BST
5 Apr 2021, 04:38 BST	21 Apr 2021, 12:29 BST
9 Apr 2021, 06:15 BST	25 Apr 2021, 18:11 BST
13 Apr 2021, 07:04 BST	29 Apr 2021, --:-- BST

*Times correct for the centre of the UK

Lunar phases in April



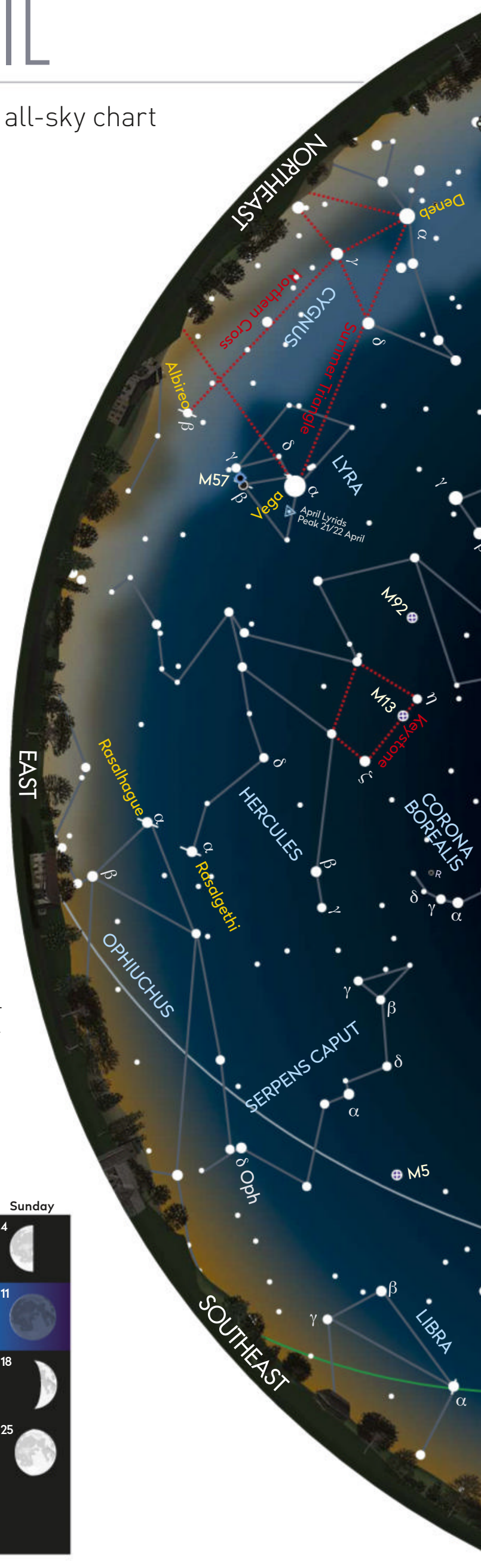
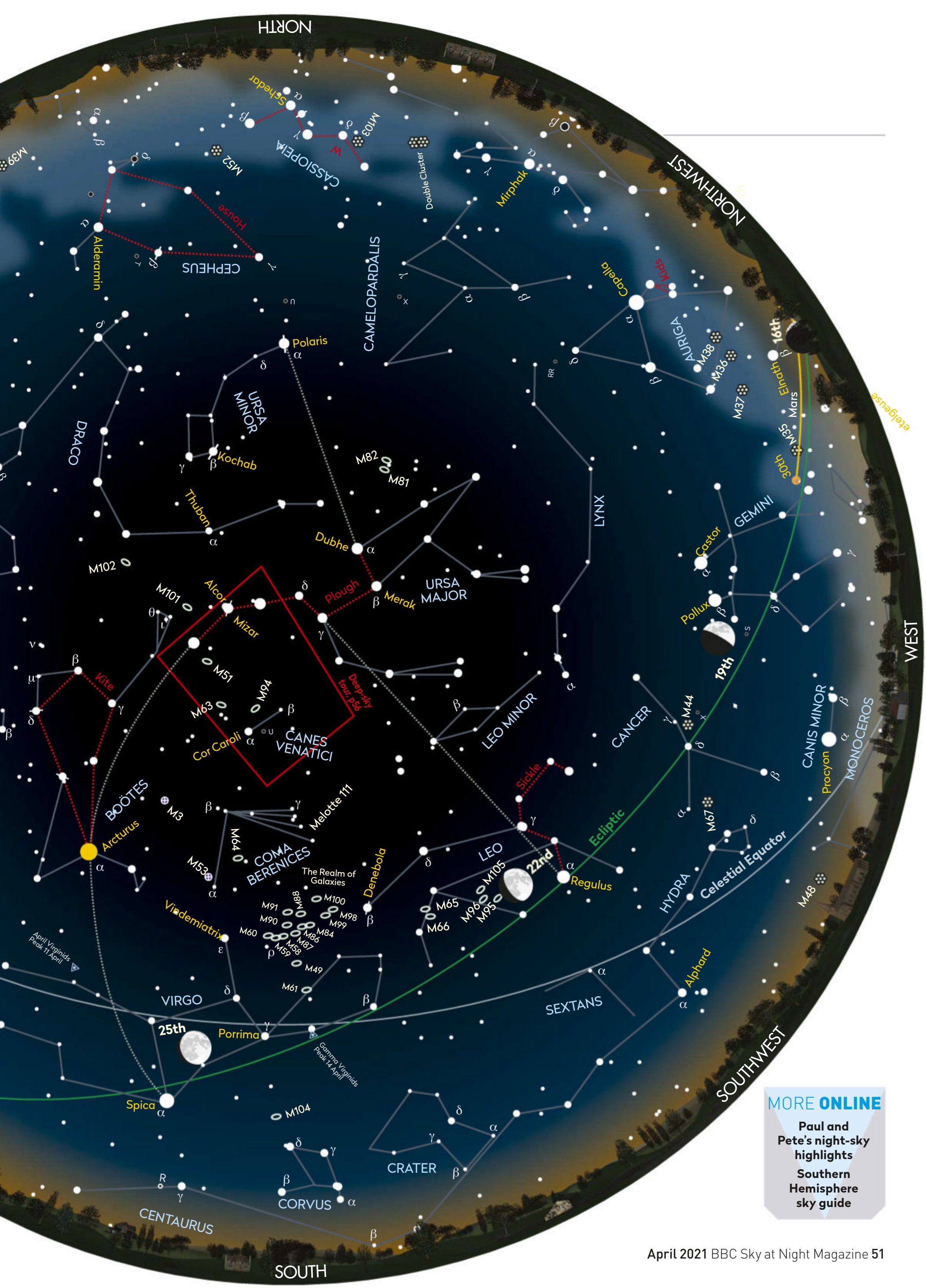


CHART: PETE LAWRENCE



MORE **ONLINE**

Paul and Pete's night-sky highlights

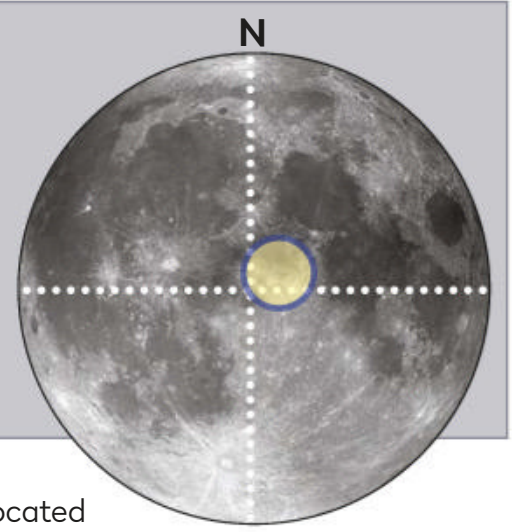
Southern Hemisphere sky guide

MOONWATCH

April's top lunar feature to observe

Hyginus

Type: Crater with associated rille
Size: 10km
Longitude/Latitude: 6.3° E, 7.8° N
Age: Between 3.2–3.9 billion years
Best time to see: Five days after full Moon (3–4 April) or six days after new Moon (19–20 April)
Minimum equipment: 100mm refractor



Hyginus is an unassuming 10km crater located near to the centre of the Earth-facing side of the Moon. It sits just to the south of 230km **Mare Vaporum**, located more or less centrally in the triangle formed by craters Manillus (40km), **Agrippa** (46km) and **Ukert** (23km).

The prominent 27km crater **Triesnecker** lies 136km to the southwest and is a good location to start from when looking for Hyginus. Triesnecker is associated with a delicate set of cracks to its east, southeast and northeast. Known as **Rimae Triesnecker** or the Triesnecker Clefts, these are fascinating to explore at times when the lunar terminator is close by. At such times, these 2km-wide cracks become more obvious, the low Sun-angle really exaggerating their appearance. The northeast clefts head towards 8km **Hyginus A** and from there, Hyginus is just a short hop of 47km further to the northeast.

Hyginus has an interesting appearance. Its steep sides lead down to a flat floor, and its northern edge is interrupted by another depression: a bean-shaped feature of similar depth to Hyginus. However, it's the regions immediately east and west of the main crater that are most impressive. Hyginus sits at the centre of an extensive structure known as **Rima Hyginus**. This is comprised of two parts, one running to the northwest for around 100km, and one extending to the east-southeast for a similar distance.

The rille is fascinating in that it appears to comprise a graben – a region of the lunar surface between two faults which has dropped in height – together with sequences of craterlets along several sections. The graben is 2km across at its widest point; the most prominent of the rille craterlets, located 21km northwest of Hyginus, is 5km across.

Hyginus is one of the few lunar craters that hasn't been formed by an impact event

Despite evidence of disturbance in the east-southeast section, it's the northwest part of the rille which is most impressive. Immediately northwest from Hyginus along the rille is a pair of small co-joined craterlets, each about 3km in diameter. Keep going along the rille to find a 3.4km craterlet with a 1.4km crater touching its eastern rim.

A further 7km along the rille brings you to the largest craterlet, roughly 5km in diameter and the start of a chain of smaller features that occupy the next 22km of the graben. A total of 10 craterlets appear chained together here with only a small gap between numbers 5 and 6.

Hyginus is unusual in that it's one of the few lunar craters that hasn't been formed by an impact event. Rather, it's thought to be a volcanic caldera. The rille is believed to have formed from a process where lava runs under the lunar crust. The resulting 'lava tube' eventually collapses, forming the rille we see today. Volcanic pits produce the incredible line of connected craterlets running along the main rille.

The eastern section of the rille appears to split in two, one part heading off towards the east-southeast, while the other has a more easterly direction. This part connects to another impressive graben known as **Rima Ariadaeus**, which runs for 220km with a width of 7km.

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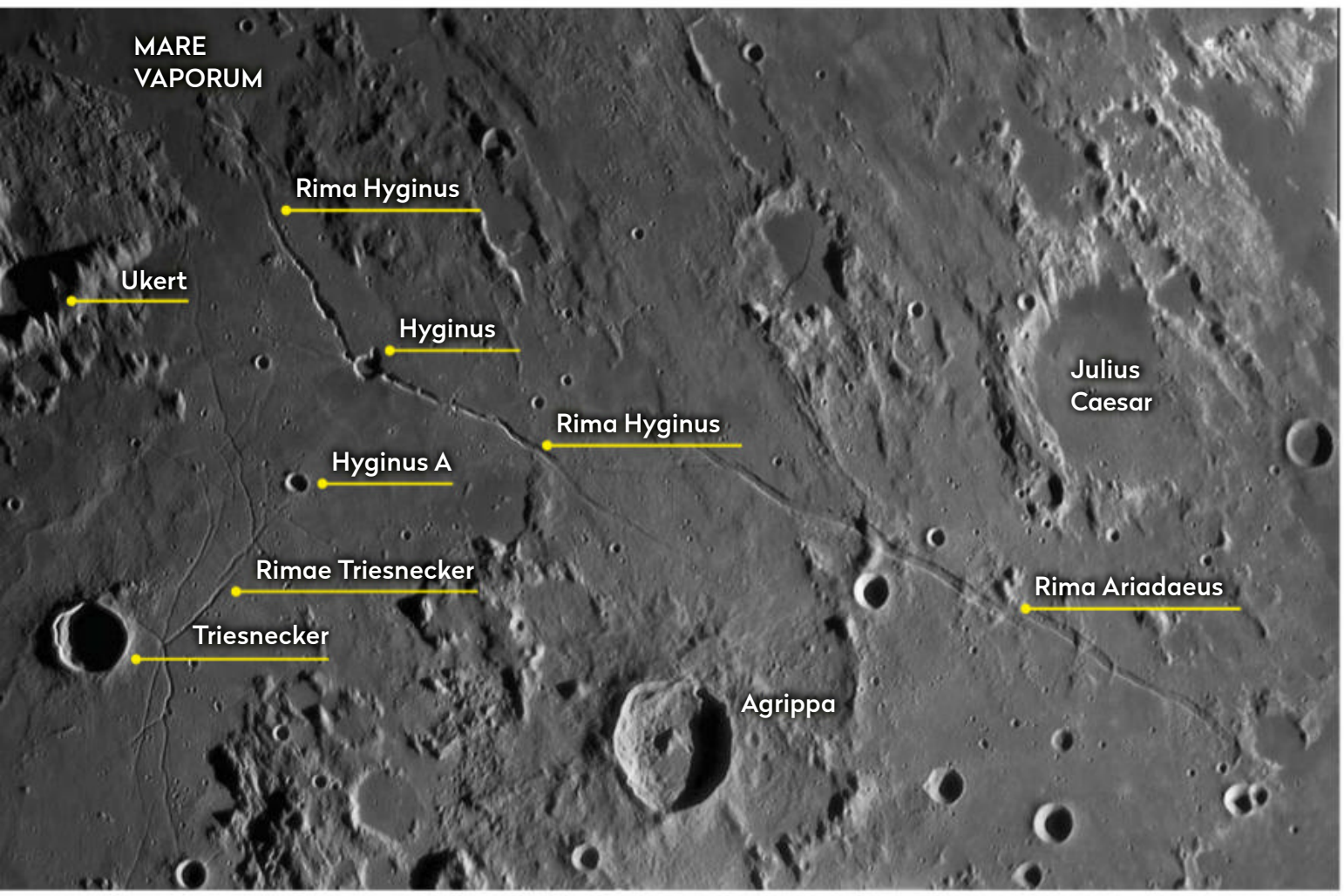
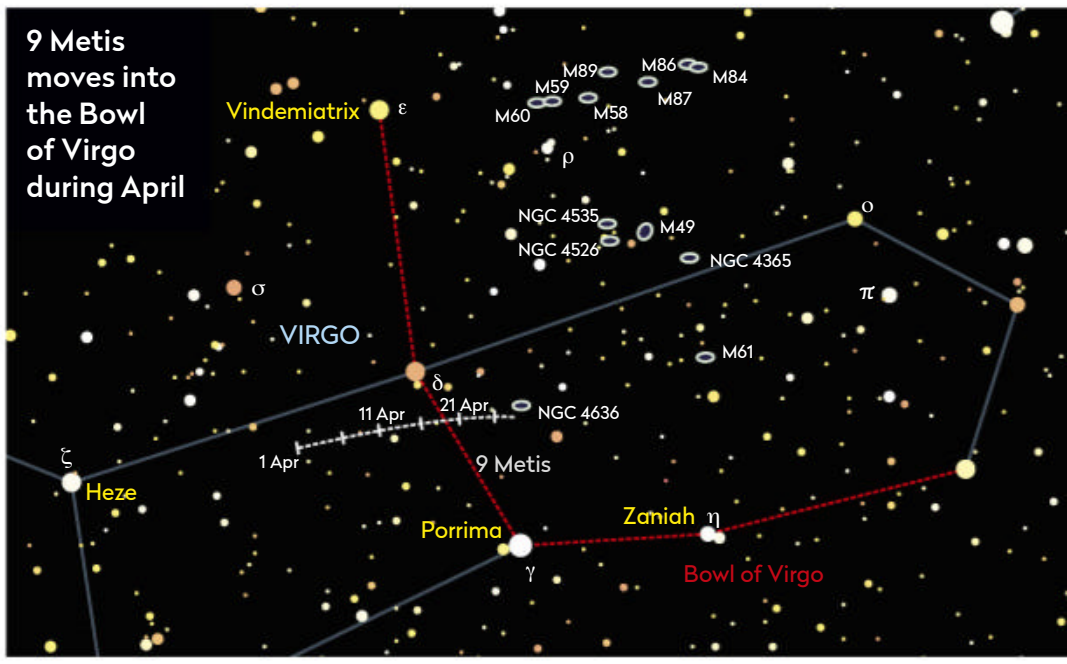


▼ To find the crater Hyginus, begin by locating Triesnecker to its southwest

COMETS AND ASTEROIDS

Catch asteroid 9 Metis as it reaches opposition in the constellation of Virgo



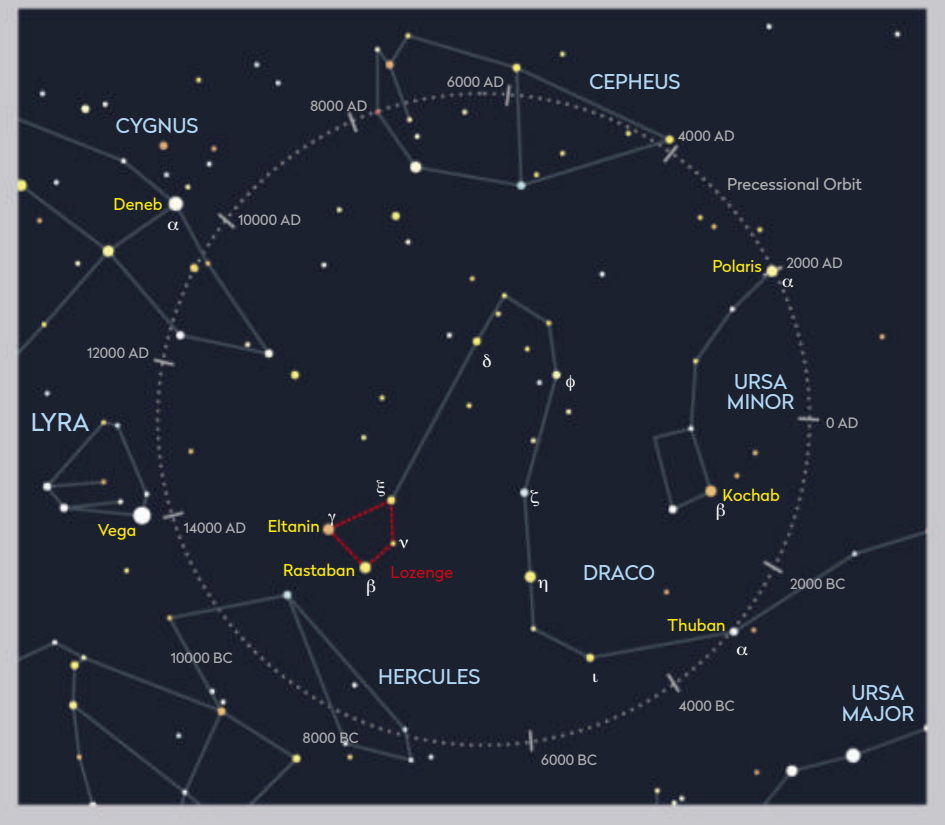
Asteroid 9 Metis reaches opposition in Virgo on 4 April, before it drifts into the large Bowl of Virgo asterism towards the end of the month. On 1 April, Metis shines at mag. +9.5 and is located 4° southeast of mag. +3.4 Delta (δ) Virginis. Its apparent movement drifts it westward, arcing slightly north as it goes. Metis remains at mag. +9.5 when it reaches opposition, slowly dimming over the rest of the month to reach mag. +10.1 by the 30th. As a result, Metis is an object that should be relatively straightforward to locate and track with a small telescope over the month. During a favourable opposition Metis is able to reach mag. +8.1, putting it within binocular range. During 2021 average binoculars may struggle to see its star-like dot moving through Virgo.

Metis is a main belt asteroid, located within a vast belt of similar objects that orbit between Mars and Jupiter. It is a large S-type (siliceous) asteroid, a term used to describe a body that has a stony or mineralogical composition. The size of a non-spherical body like Metis is normally expressed in terms of the closest fitting tri-axial ellipsoid which will fit around it. A tri-axial ellipsoid, as its name suggests, is a three-dimensional elliptical volume with separately expressed dimensions in each dimension; for Metis it would measure 222km x 195km x 140km.

In reality, the true shape of Metis won't occupy the full extent of its stated tri-axial ellipsoidal volume, and measurements of the variation in reflected light from Metis suggest that one end has a more tapered profile. Metis takes 3.69 years to complete each orbit around the Sun, its orbital distance varying from a maximum value (aphelion) of 2.68 AU to a minimum value (perihelion) of 2.10 AU.

STAR OF THE MONTH

Thuban, the former Pole Star in Draco



▼ **The 26,000-year movement of the North Celestial Pole**

Thuban, the alpha star of Draco, the Dragon, is perhaps a strange choice to carry this prime position title. It shines at mag. +3.7, making it a medium brightness star erring on the dimmer side. In terms of Draco, it's easily outshone by some of the other stars that form this long curving constellation, which appears to wrap around Ursa Minor, the Little Bear, and of course the Pole Star, Polaris (Alpha (α) Ursae Minoris). Eltanin (Gamma (γ) Draconis) is 3.7 times brighter than Thuban at mag. +2.2.

Thuban's elevated status comes from the fact that Earth's rotational axis wobbles over time. It takes 26,000 years for the axis to complete one orbital wobble and as it does so, the star which carries that important celestial position – the marker for the North Celestial Pole – changes.

Currently it's Polaris which carries this mantle, but between the 4th to 2nd millennium BC, it was Thuban that marked the position of the Pole, most demonstrably between 3,942–1,793 BC. It will regain this important position in the sky, but not until 20,346 AD.

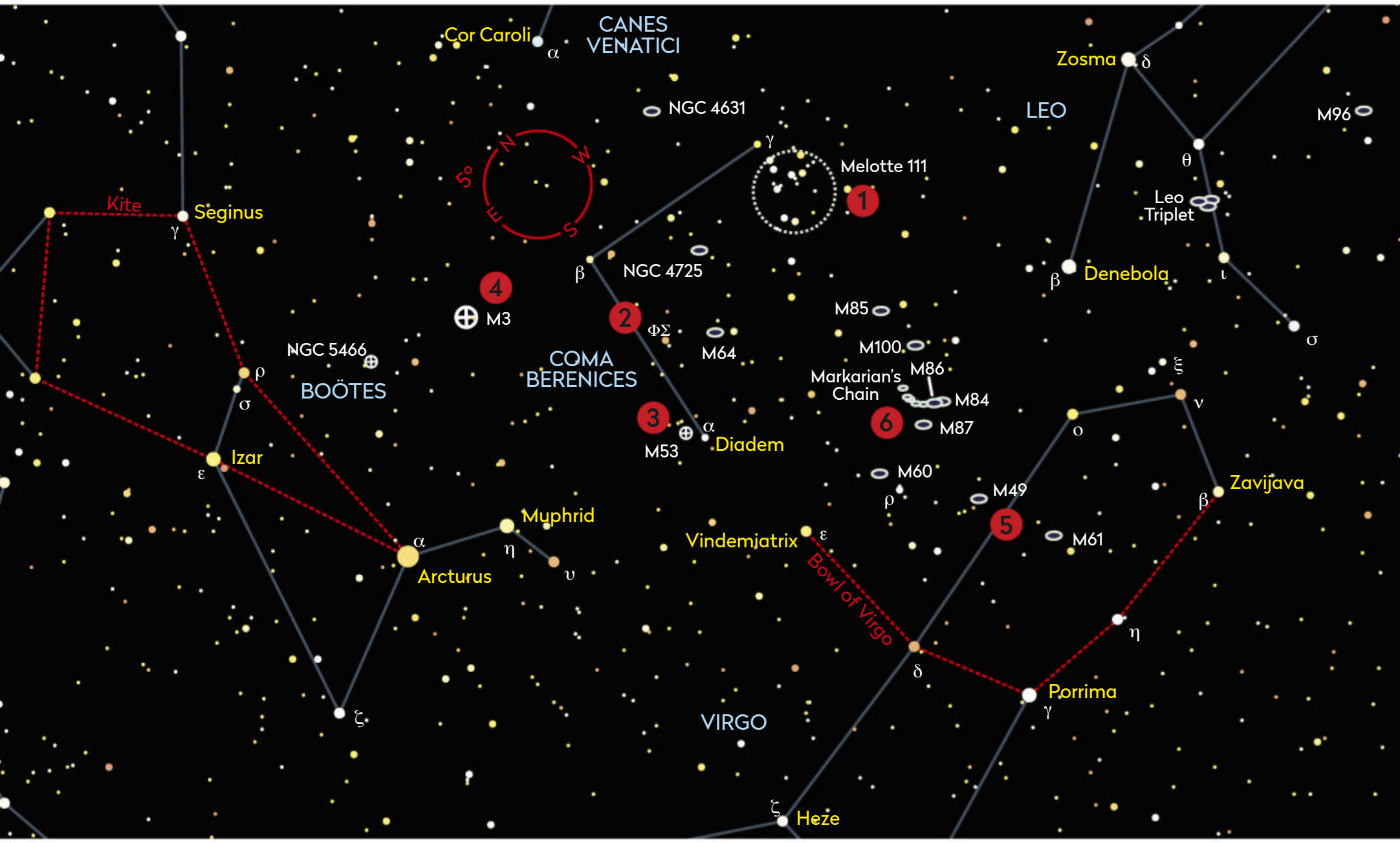
Thuban is a white giant star and a spectroscopic binary, with a spectral class of AOIII; in fact, it's used as a reference marker for all AOIII stars. It lies at a distance of 303 lightyears away and is 2.8 times as massive, 3.4 times larger and 479 times more luminous than the Sun.

From the UK, Thuban's northerly declination means that it never sets below our horizon, a location described as being circumpolar.

BINOCULAR TOUR

With Steve Tonkin

Our wide-field gems include Markarian's Chain and spectacular globular cluster M3



1. Melotte 111

10x 50 If there is a celestial object that seems to have been 'made for binoculars' it's this one. Look midway between Cor Caroli (Alpha (α) Canem Venaticorum) and Denebola (Beta (β) Leonis) and you should be able to see, with the naked eye, a misty patch of sky about 6° across. Your 10x50 binoculars will reveal 30 or so stars filling the field of view, all mag. +10.5 or brighter; there are no fainter stars, due to a phenomenon called mass segregation. ☐ **SEEN IT**

2. FS Comae

10x 50 Identify Beta (β) Comae and Diadem (Alpha (α) Comae), go to a point midway between them and navigate a degree to the west. There you will find the orange star FS Comae shining around mag. +6. The magnitude of this semi-regular variable star varies between mag. +6.1 and +5.3 with a period of 55 to 58 days. ☐ **SEEN IT**

3. M53

10x 50 A degree north-east of Diadem you'll find a small misty patch, which will appear to grow in size, fuzziness, and brightness if you centre it in the field of view, then avert your gaze back to Diadem. This is M53 and the apparent changes you just witnessed, which are typical of globular clusters, demonstrate the difference between direct and averted vision. Practise this technique, which you will need later when we hunt for the galaxies in Markarian's Chain. ☐ **SEEN IT**

4. M3

10x 50 Next is one of the best globular clusters in the northern sky, but there are no nearby bright locator stars. If you look halfway between Diadem and Seginus (Gamma (γ) Boötis), you should find what looks like a badly focused star in the field of view. With averted vision you'll see more of the glow from the nearly half-million stars that comprise M3. ☐ **SEEN IT**

5. M49

15x 70 Locate Rho (ρ) Virginis and place it on the northeast of your field of view. On the opposite side you should find a pair of 6th magnitude stars, just over a degree apart and orientated southeast-northwest. M49 is a small, oval patch of light between this pair. Try using averted vision and you should detect several more galaxies in this region, in the direction of Mel 111. How many can you see? ☐ **SEEN IT**

6. Markarian's Chain

15x 70 This galaxy chain lies about half way between Vindemiatrix (Epsilon (ε) Virginis) and Denebola (Beta (β) Leonis). It should be no problem finding them, but it's easy to get lost as you switch between direct and averted vision. Start with M84 and M86 and once you've got these you should be able to identify the seven brightest galaxies in the chain. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 2

THE SKY GUIDE CHALLENGE

Plot the variation between the mean Sun and apparent Sun over the course of a year

There are two Suns in our sky – one is real and one conceptual. The conceptual or 'mean' Sun is important because it allows us to stabilise the length of our days. The real or apparent Sun oscillates in position either side of the mean Sun, and this is what we are attempting to reveal for this month's challenge. Actually, this will take more than a month – it'll take a year!

The apparent speed of the real Sun in the sky varies over the course of a year due to two effects – the axial tilt (obliquity) and orbital ellipticity of Earth. These affect the apparent position of the Sun, their combined effects generating a value known as the 'Equation of Time'. This oddly named commodity varies in value over the year. Apparent time can become 16m33s ahead of clock time around 3 November or 14m06s behind it around 11 February. Apparent time and clock time only match (when the Equation of Time = 00m00s) around 15 April, 13 June, 1 September and 25 December.

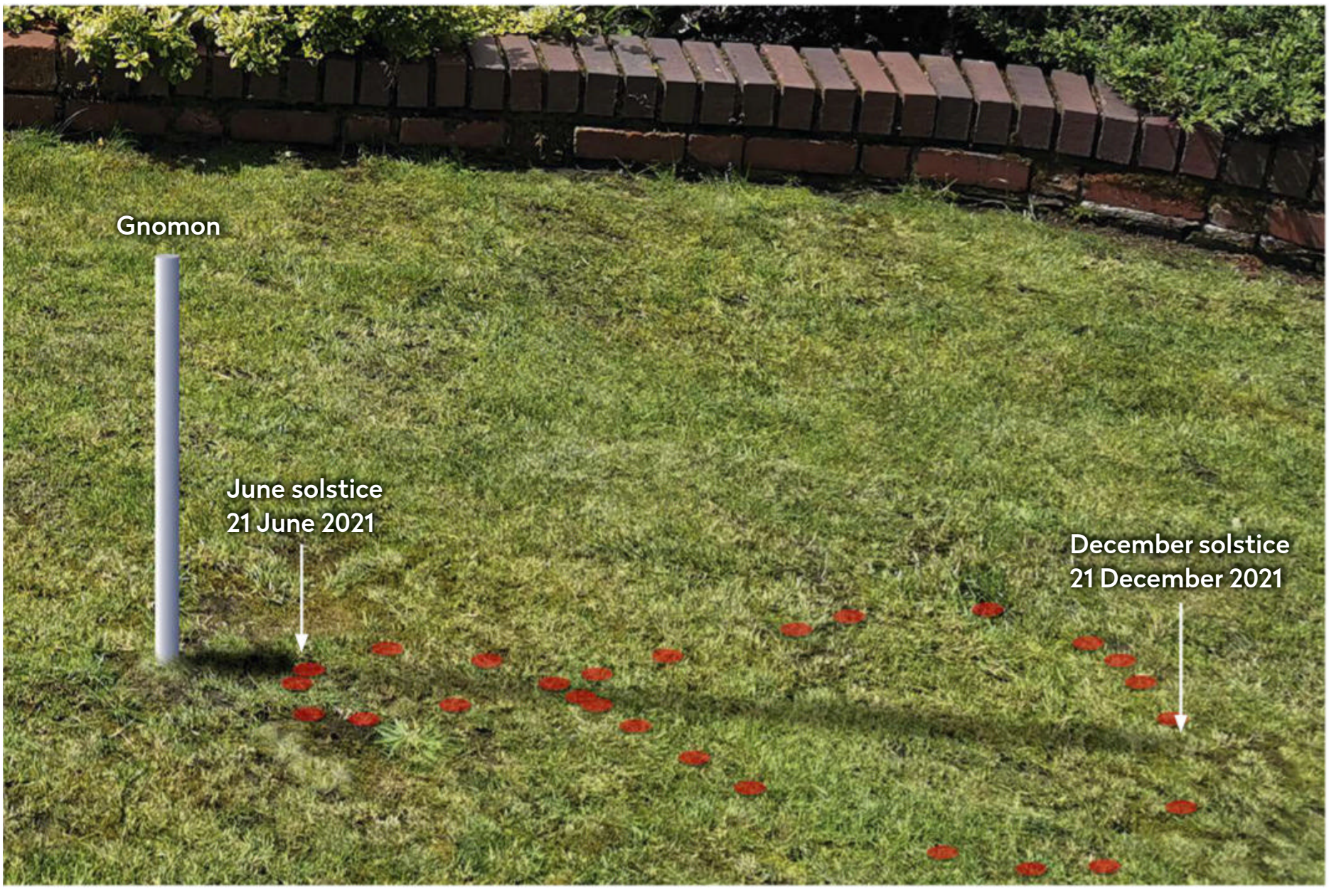
The real or apparent Sun oscillates in position either side of the mean Sun

The mean Sun represents the position of the Sun corrected for the Equation of Time. For example, the mean Sun always sits due south at midday UT, while the apparent Sun mostly doesn't, depending on the date and the prevailing value of the Equation of Time. If you have a patient disposition, the variation can be shown using a gnomon, basically a shadow casting stick or structure. Ideally, the shadow needs to fall on a large flat area.

All you need to do is mark the position of the gnomon's shadow tip at the same UT time of day over the course of a year. In reality this won't be possible due to life events and the weather of course, but this shouldn't be an issue as long as you can create one shadow mark at least approximately every 10–14 days. How you make each mark is up to you, but be aware they need to survive the rigours of being outdoors for at least a year.

Location is important. Consider where the shadow will fall over the course of the year. Midday UT is a good time to aim for, but make sure the Sun doesn't get blocked by foreground structures near the December solstice when it'll appear lowest in the sky.

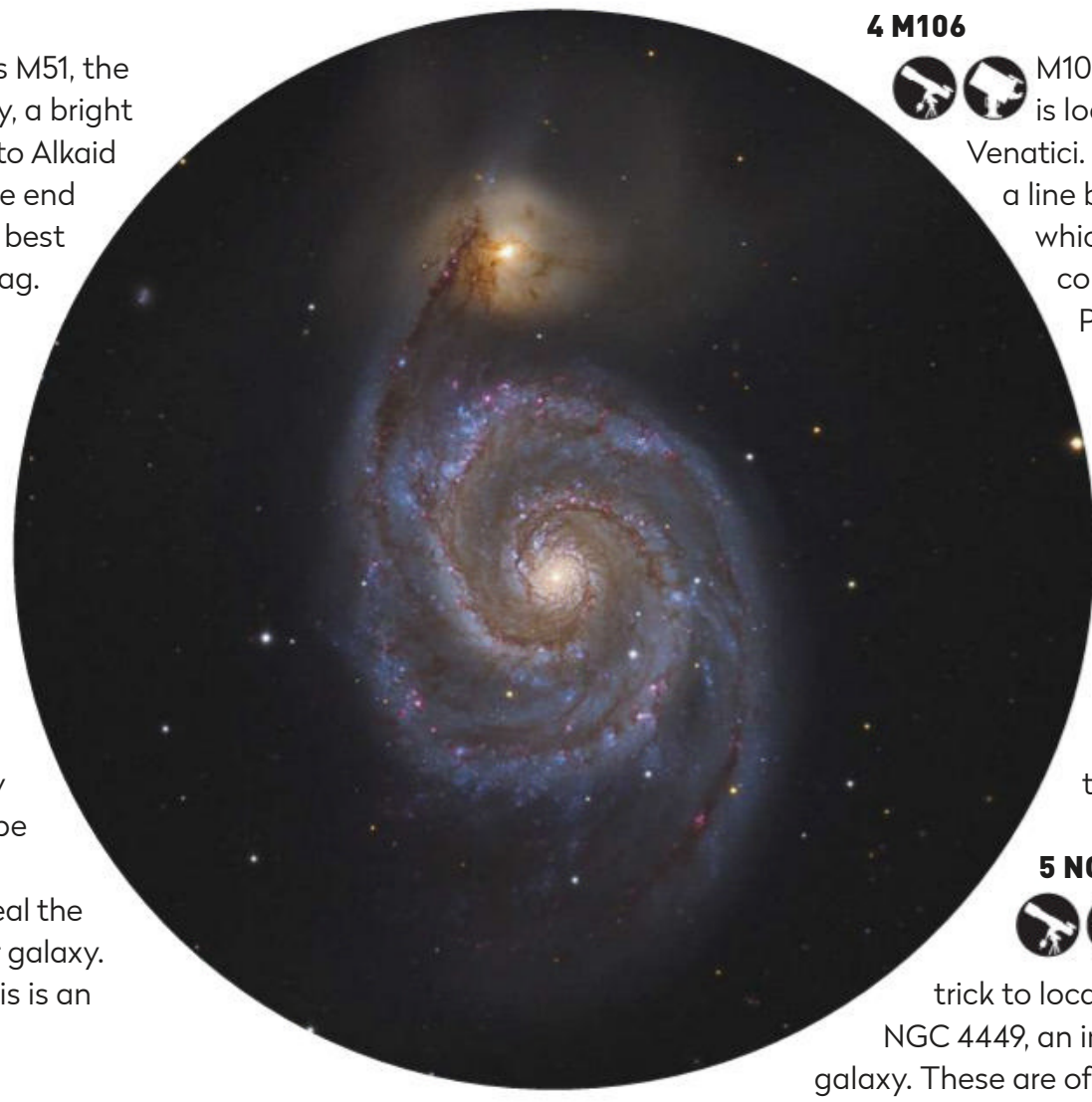
If you manage to see this long-term project through, the pattern revealed may surprise you. The plot shows the solar analemma, a shape reminiscent of a bowling pin. This is the physical depiction of the Equation of Time, a direct representation of how Earth's axis and orbit affects the real position of the Sun in our sky.



▲ Use a gnomon (a shadow-casting stick) to plot the Sun's real position in the sky, or solar analemma, in a shape resembling a bowling pin

DEEP-SKY TOUR

This month's survey stops off at the Whirpool and Sunflower Galaxies



▲ **Begin this month's tour with the magnificent Whirpool Galaxy, M51**

1 M51

Our first target is M51, the Whirlpool Galaxy, a bright spiral galaxy located close to Alkaid (Eta (ε) Ursae Majoris) at the end of the Plough's handle. The best way to locate it is to find mag. +1.8 Alkaid (Eta (η) Ursae Majoris) and mag. +4.7 24 Canum Venaticorum as two vertices of a squat isosceles triangle with M51 located at the remaining vertice. There are two tidally interacting galaxies here, mag. +8.4 M51a (NGC 5194) and mag. +9.6 M51b (NGC 5195). They appear similarly bright through a small scope although M51a is larger. A 250mm instrument will reveal the whirlpool arms of the larger galaxy. Presented face on to us, this is an amazing sight. ☐ **SEEN IT**

2 M63

To locate M63, the Sunflower Galaxy, imagine the arc of the Plough's handle as part of a circle. Roughly close to where the circle's centre would be located is mag. +2.9 Cor Caroli (Alpha (α) Canum Venaticorum). Imagine a line from Alkaid to Cor Caroli, and from there the point two-thirds along this line from Alkaid. M63 lies 0.7° southeast of this position. This is a bright spiral galaxy, shining with an integrated magnitude of +8.6. Its tilt is greater than M51, leading to an elliptical glow through a 150mm scope, brightening to a star-like centre point. ☐ **SEEN IT**

3 M94

M94 is easy to locate. From Cor Caroli, head northwest for 5° to locate mag. +4.2 Chara (Beta (β) Canum Venaticorum). Locate the mid-point of the line joining these stars and head northeast, at right angles to the line, towards the handle of the Plough for 1.6°. This will bring you face to face with M94, a beautiful and bright star mag. +8.1, face-on spiral galaxy. Larger instruments begin so show irregular brightness distribution, the bright core dominating the scene. ☐ **SEEN IT**

4 M106

M106, an intermediate galaxy, is located within Canes Venatici. Locate M106 by imagining a line between Chara and the star which marks the southeast corner of the Saucepan's pan, Phecda (Gamma (γ) Ursae Majoris). M106 lies close to the midway point of this line. Through a small instrument, mag. +8.3 M106 appears mottled in texture, with a bright core. Larger instruments show an elongated object. Two bright sections of M106's spiral arms flank the core. ☐ **SEEN IT**

5 NGC 4449

We can use the same mid-point dividing trick to locate our next target, NGC 4449, an irregular Magellanic-type galaxy. These are often dwarf galaxies with a single spiral arm. The prototype is the Large Magellanic Cloud, a Milky Way satellite, only visible from the Southern Hemisphere. NGC 4449 lies at the mid-point of the line from M106 towards Chara, or one quarter the way along the Chara-Phecda line.

The galaxy is around 10th magnitude and is visible through a small instrument as a 2-arcminute elongated smudge of light. This is the core of the galaxy. Larger instruments expand the amount of core that can be seen along with revealing more internal detail. This tends to manifest itself as bright mottled patches. A 300mm scope will reveal structure that belongs to the galaxy's singular spiral arm. ☐ **SEEN IT**

6 NGC 4490

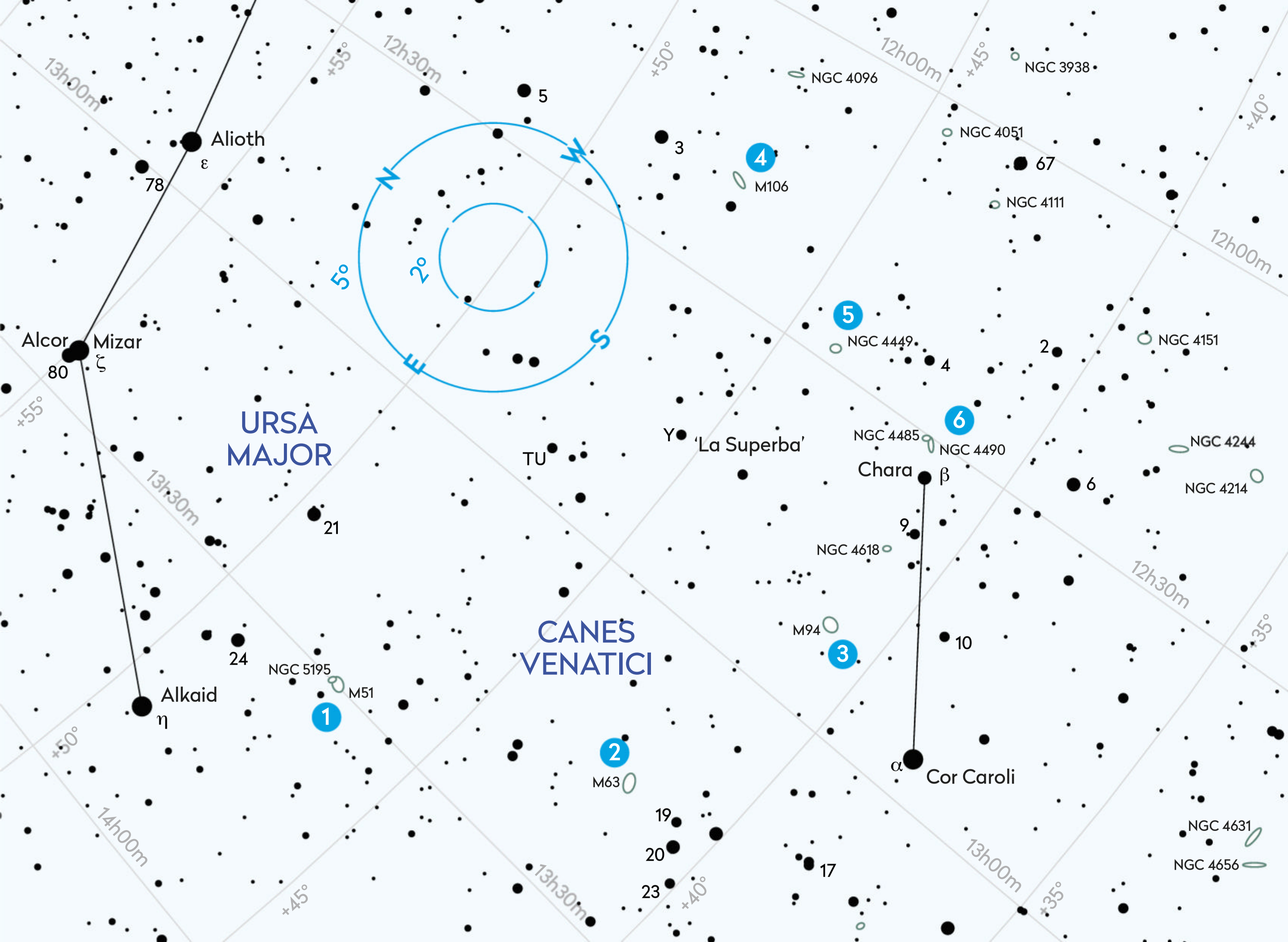
NGC 4490 lies 41 arcminutes to the west-northwest of Chara; alternatively, extend the line from Cor Caroli through Chara for a little over 10 per cent of that distance again and you'll be pointing right at NGC 4490. Also known as the Cocoon Galaxy, NGC 4490 is a barred spiral that has an interacting companion in the form of the starburst galaxy NGC 4485. NGC 4490 has an integrated magnitude of +9.8 and appears several times larger and more elongated than the roughly circular appearance of mag. +12.0 NGC 4485. Both objects can be seen as separate glowing areas through a 150mm scope, the galaxy cores separated by around 3.5 arcminutes; larger instruments close the gap. ☐ **SEEN IT**

JOHANNES SCHEDLER/CCDGUIDE.COM, CHART BY PETE LAWRENCE

This Deep-Sky Tour has been automated ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions.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M51
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NGC 3938
NGC 4051
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6
NGC 4485
NGC 4490
NGC 4244
Chara
β
6
NGC 4214
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NGC 4618
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M94
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17
NGC 4631
NGC 4656
Y
'La Superba'
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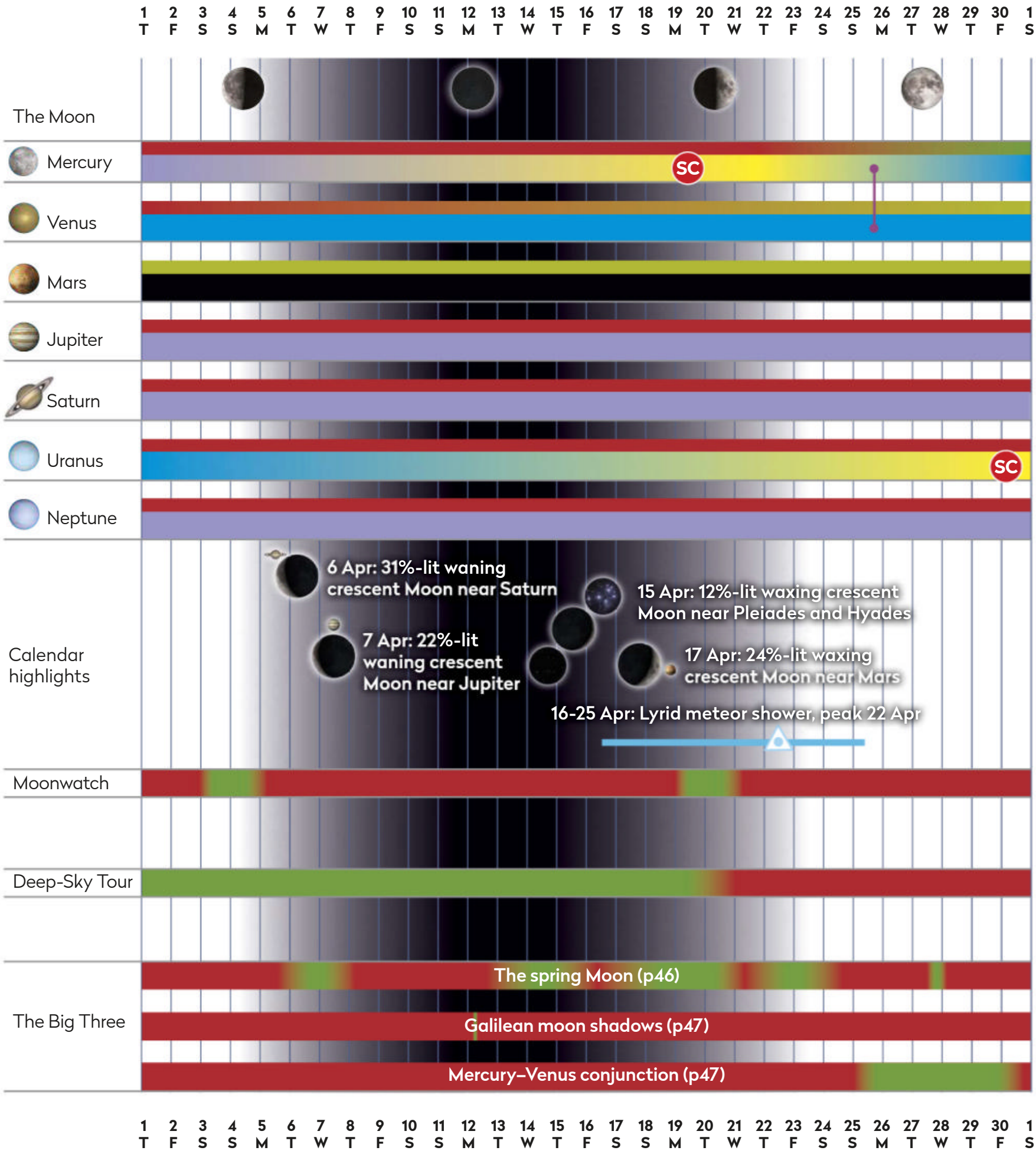
AT A GLANCE

How the Sky Guide events will appear in April



KEY

CHART BY PETE LAWRENCE

BBC Sky at Night MAGAZINE

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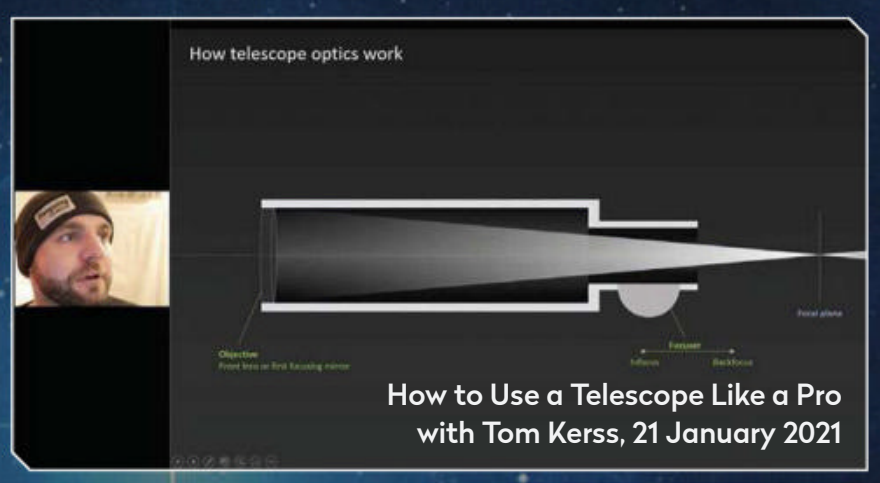

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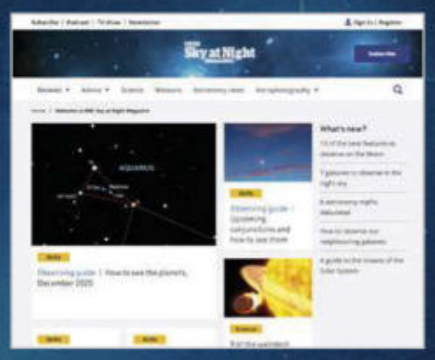

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Against the odds: official documents reveal that Yuri Gagarin's historic trip to space was almost cancelled

Around the world in 108 MINUTES

In 1961, Yuri Gagarin became the first human to reach space. For decades, the truth of his journey was obscured behind Soviet secrecy. Sixty years after his initial flight, **Ezzy Pearson** lifts the curtain on what really happened

1961. Less than four years after it had launched the satellite Sputnik, the Soviet Union was locked in a tense race with the US. The Soviets had bagged every major milestone to this point – first satellite, first living creature, first lunar impact – but they knew that if they could launch a human before the US, it would cement their reputation as the space superpower.

It was the most closely run leg of the entire Space Race. Though the Soviets gave away little in public, the US were ensuring the entire world knew that their astronaut, Alan Shephard, was on course to triumph over their Space Race competitors.

On 12 April 1961, Shepard's flight was just three short weeks away when the announcement sounded out across the Soviet Union – at 9:07am that morning, Yuri Gagarin had blasted off from the Baikonur Cosmodrome in a Vostok-1 rocket and had become the first human in space. For 108 minutes, he circled the Earth before arriving back on the ground safely.

Gagarin was a national hero and, taken unawares, the US was humiliated.

Those initial announcements depicted a flight entirely without flaw: a perfect victory over the US. In fact, the flight had almost been a disaster several times over. Over the last 60 years, the truth of what happened has slowly emerged and 10 years ago, on the 50th anniversary of the flight, the Russian government released hundreds of official documents about the mission.

It's now apparent that the mission was almost cancelled before it began. During a last-minute weigh-in the night before the flight, the ground crew realised that the combined weight of Gagarin, his spacesuit and his seat were 13kg over the limit. The engineers worked through the night to remove every piece ▸

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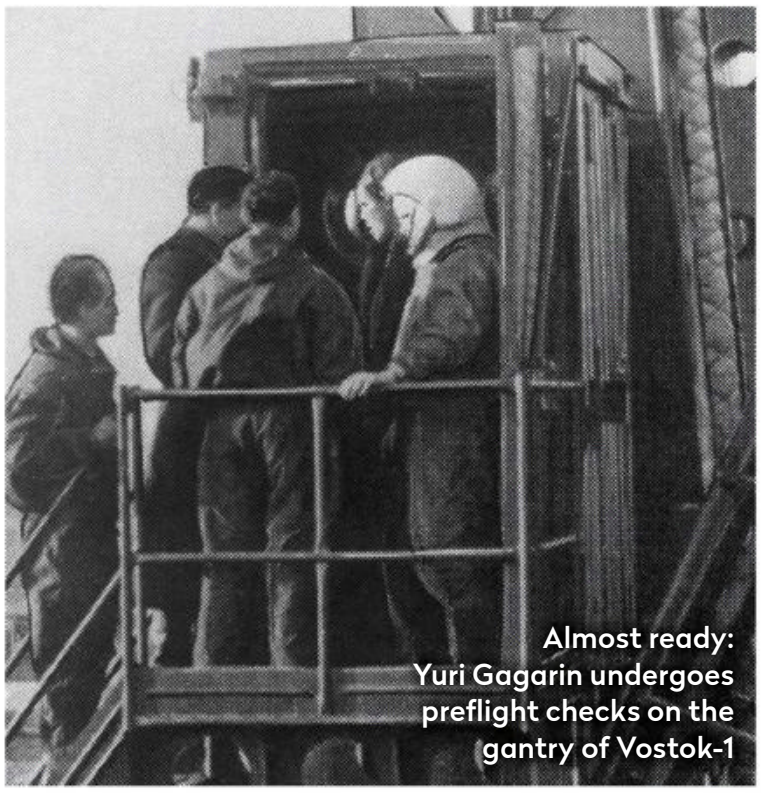
ILLUSTRATION

BBC Sky at Night MAGAZINE

VIRTUAL LECTURE

Join our online talk, **Yuri Gagarin – The Untold Story of the First Human in Space**, by documentary director and author Stephen Walker, on 23 April, 7pm GMT. For details see **www.skyatnightmagazine.com/virtual-lecture**



Almost ready: Yuri Gagarin undergoes preflight checks on the gantry of Vostok-1

Relaxed approach: the cosmonaut at the controls of the Vostok-1 capsule

▲ **Making history: Vostok-1 launches at 9:07am Moscow Time and subjects Gagarin to intense g-forces during its ascent**

▸ of equipment that didn't need to be there and fix any damage they created along the way.

Meanwhile, Gagarin and his back up Gherman Titov, were having a much more relaxing time. They were under strict instructions not to discuss the coming mission and instead spent the night playing pool and chatting about their lives before becoming cosmonauts. Both were sent to bed at 9:30pm, but apprehension about the coming day meant neither managed to sleep that night.

Preparing for launch

Gagarin was roused at 5:30am and gifted with a bunch of tulips from a local woman's garden. He didn't shave – it was considered bad luck by Soviet pilots – but instead ate a breakfast of tubed food, similar to those he'd be trialling later during the flight. Afterwards, Gagarin donned his newly lightened spacesuit and boarded the special bus to take him to the launch pad.

On the horizon, the 30m-tall rocket rose up, a shining spire of silver against the background blue of the sky.

"The closer we got to the launching pad, the larger the rocket grew, just as if it were changing size," Gagarin would later recall in his autobiography, *Road to the Stars*. "It looked like a giant beacon and the first ray of the rising Sun shone on its pointed peak."

Gagarin was swiftly loaded into his Vostok capsule before the technicians began hermetically sealing him away from the world, ready for launch. Only, the door wouldn't shut. The crew set about hastily unscrewing panels to reach the problem, managing to fix it with enough time to make the launch. Meanwhile, Gagarin joked with his colleagues over the radio and sang to himself.

Soon enough, it was time to prepare for launch. Two minutes before launch Gagarin began to feel the rocket sway and move as it readied itself before, at 9:07am Moscow Time, the engines of the R7 roared into life. Inside the capsule, Gagarin let out a victorious yell of "Poyekhali! [Let's go!] Goodbye until we meet soon, dear friends."

As the rocket rose through the air, Gagarin was subjected to intense g-forces, his heart rate rising to 150 bpm. The intense conditions of launch obscured

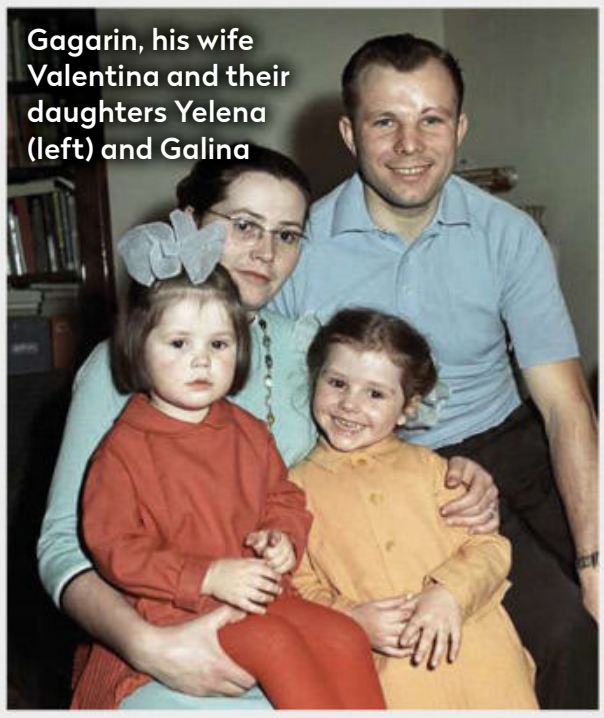
The life of a legend

Yuri Gagarin's flight took him from foundry man to international superstar

Born on 9 March 1934 on a collective farm in the village of Klushino, 200km west of Moscow in the Smolensk Oblast province, Yuri Gagarin's fascination with flying machines began at an early age. He spent many of his school days building model aircraft and learning about the Soviet air heroes of the Second World War.

At 16, he was employed by the local foundry and quickly earned himself a place at a technical school in Saratov, where he joined a local flying club. By 1955, he was enrolled at the Air Force's pilot school where he met and married Valentina Goryacheva – the couple went on to have two daughters.

By 1959, Gagarin was secretly selected for the first ever class of cosmonauts, where he proved himself capable and popular. When the Vostok-1 mission was being selected, he was a clear frontrunner alongside his colleague Gherman Titov. In the end, Gagarin's rise from a farm to a foundry to the stars was seen as the best embodiment of Soviet ideals.



Gagarin, his wife Valentina and their daughters Yelena (left) and Galina

Afterwards, Yuri Gagarin became an international celebrity. Though he was initially kept on as a cosmonaut, when the first flight of the new Soyuz craft resulted in its pilot's death, Gagarin was deemed too valuable an asset. He was banned from spaceflight permanently.

But despite this precaution, on 27 March 1968 Gagarin was killed when the MiG-15UTI fighter jet he was flying crashed during a training exercise. Today, dozens of streets and towns bear his name, while monuments to him can be found worldwide, commemorating the man who rose from the Earth to reach the stars.

ILLUSTRATION

▲ **World of wonder: once in space, Gagarin saw views of Earth that no human had ever seen before**

the radio signal, while the intense g-forces made it difficult for him to speak. For one agonising minute, the technicians could do nothing but wait for the signal to return and let them know that their colleague was still safe, racing upwards on his journey towards the stars.

When Gagarin's voice did come back on the air, however, it was free of apprehension.

"I see Earth," he said, the first time human eyes had seen such a view. "I see the clouds. It's beautiful. What beauty!"

As he continued to rise, he reported back his "buoyant mood" and how smoothly the flight was going. A little too smoothly, it would turn out. The engines failed to cut out when they were meant to and Gagarin ended up overshooting the intended altitude of 230km, instead reaching 327km.

Meanwhile, the Soviet media machine was beginning to swing into operation, announcing that the mission had launched flawlessly and was on course for success.

In orbit, Gagarin got to work – though this wasn't to include actually piloting the spacecraft. Despite being a highly qualified pilot, Soviet psychologists feared that the experience of weightlessness and seeing Earth from above would completely unravel the human mind. Believing that Gagarin could be mentally incapacitated and crash the spacecraft, he'd been locked out of the controls. The spacecraft did carry an envelope with a code to release the controls but it was only supposed to be opened in an emergency – a fact that didn't sit well with several of the ground staff, who had secretly told Gagarin the code in the run-up to launch.

Keeping stable

Gagarin didn't lose his wits, however. Instead, he easily acclimatised to the strange experience and seemed to be quite enjoying himself.

"Feeling of weightlessness is interesting," he said during the flight. "Everything floats. Floating is everything. Wonderful! Interesting."

With Earth's gravity falling away, Gagarin found himself able to move about more easily than he could on Earth. Between making notes in his logbook, he would let his writing pad and attached pencil float in front of him, marvelling at how they were suspended in microgravity. When he caught it to make his next report, however, he found the pad but not the pencil. It had become untethered and floated off, never to be seen again.

Unable to make notes, he moved onto trialling the food and water tubes that his fellow cosmonauts would need on longer missions. While proving that ▸

MAP REFERENCE: ANATOLY ZAK/RUSSIANSPACEWEB.COM

▸ he could consume these without Earth's gravity, a drop of water escaped from the water tube and Gagarin took a few moments to marvel at the perfect sphere of water, suspended in the air.

Back on Earth, the US has had picked up the signal of Gagarin as he passed overhead. While the CIA prepared a report for President Kennedy, NASA broke the news to Alan Shepard that he wouldn't be the first human to reach space.

Meeting expectations

Gagarin's flight was only ever intended as a short test. After 78 minutes, the spacecraft prepared to return to Earth – a stage that, unbeknownst to Gagarin, had become far more perilous than initially planned. The flight path had been designed so that the atmospheric drag would naturally deorbit the spacecraft, and there was 10 days' worth of food, water and air so that Gagarin would be able to survive the wait. However, because the Vostok had overshot its intended altitude to a height where the air was much thinner, it would now take 20 days to return. As there was nothing to be done but hope the engines worked, the cosmonaut wasn't told of his predicament.

With no idea of the risk, Gagarin closed his helmet, secured his seat straps and waited for the engines to fire. To the relief of everyone on the ground, they did.

For 42 seconds, Gagarin felt the spacecraft slowing, only for the deceleration to end with a sudden jolt. His descent module had separated from the instrument module as expected, but the tether connecting them had failed to release. The unwieldy straggler was causing the capsule to spin out of control. The Sun flashed through the windows, dazzling Gagarin, while the g-forces caused his vision to go grey as blood was forced from his brain. Despite this, Gagarin remained calm, reporting his situation back to the ground.

For 10 minutes the temperature climbed rapidly, threatening to incinerate the pod until there was a final bang – the tether had burned through. The instrument module shot off, as the descent module righted itself into its correct orientation.

At an altitude of 7km from the surface, the capsule's hatch popped open before Gagarin's seat ejected and deployed its parachute. Beneath him, Gagarin could see the silver line of the Volga River winding through the Saratov region of Russia – the

▲ Shortfall: Gagarin and his capsule landed separately (at 10:55am and 10:57am respectively) near Saratov, far short of the intended site at Pestravka, but it was still a good result for the first ever crewed spaceflight

GLOBE TURNER/LLC/ISTOCK/GETTY IMAGES, ITAR-TASS NEWS AGENCY/ALAMY STOCK PHOTO X 2, SPUTNIK/SCIENCE PHOTO LIBRARY, MECHANICK/ISTOCK/GETTY IMAGES

Gagarin in the UK

In July 1961 the spaceman returned to his roots and met with British workers

After his historic flight, governments around the world invited Gagarin to visit – but not the UK. The cabinet of the day feared upsetting their US allies, so instead it was the trade unions who took it upon themselves to invite the Soviet hero to visit from 11 to 15 July 1961. Knowing Gagarin was a former foundryman, the Amalgamated Union of Foundry Workers took him on a tour of an engineering plant in Manchester.

During his car ride from the airport, Gagarin was greeted by packed crowds, braving the rain to see him. He quickly ordered the roof of his convertible be put down, telling the driver, "If these people can stand in the rain, so can I." Though he ended up soaked through, Gagarin never stopped smiling as he waved at the people. Months later, Gagarin would fondly recall that "the firm handshakes of my fellow workers meant more to me than many awards."

13 July 1961: Gagarin visits a factory in Trafford Park, Manchester

While at the plant itself, Gagarin told off a reporter who had stood on an unfinished casting to prevent it being spoiled. "I was a foundry worker," he said. "Although I am doing a different job now, I am still a foundry worker at heart."

Afterwards, Gagarin gave a speech at Manchester Town Hall. He drove home the point that while he was the one to fly to space, it took tens of thousands of people to get him there, and called for the East and West to work together towards a joint endeavour in space, stating, "There is plenty of room for all in outer space."

Gagarin's capsule: it remained a secret that the cosmonaut had parachuted and returned separately to the spacecraft

Dr Ezzy Pearson is *BBC Sky at Night Magazine*'s news editor. Her latest book *Robots in Space* has recently been published by The History Press

very place he'd learned to fly years before. It was 108 minutes after blast-off when Gagarin's feet touched back down onto Earth.

As he opened up his helmet to take a deep breath of terrestrial air, he spotted a woman, her granddaughter and their spotted calf watching him in confusion.

"Have you come from space?" the woman asked.

"As a matter of fact, I have," he replied, as a group of nearby farm workers ran towards him, crying out his name.

Just over an hour later, the radio proudly announced his return to "the sacred soil of our motherland". But the vision these early broadcasts conjured was very different to the flight Gagarin had just experienced. In the 'official' version, the cosmonaut hadn't ejected, but landed in the Vostok – a necessary requirement to claim the achievement under international aviation regulations. He'd also apparently landed bang on target, rather than 300km off-course, as actually happened.

Though the precise details of the story might have changed over the last 60 years, there is one thing that remains undeniable. Yuri Gagarin launched as just another citizen and returned as a hero.

VOSTOK 1 MISSION TIMELINE

All times in Moscow Time (UTC +3)

5:30am: Yuri Gagarin and Gherman Titov wake up, eat breakfast and put on their space suits.

5:45am: The cosmonauts board the transport bus and drive to the launch site.

6:50am: The bus reaches the launchpad. A worker writes CCCP on Gagarin's helmet so he isn't mistaken for an enemy pilot on his return to Earth.

7:07am: Gagarin boards Vostok-1.

9:07am: Lift-off. After a few minutes the g-forces prevent Gagarin from speaking.

9:12am: Radio contact resumes.

10:02am: Radio Moscow announces the launch.

10:25am: Vostok-1 returns to the atmosphere. Shortly after, the instrument module fails to detach fully, sending the descent module into a spin.

10:35am: The craft stabilises after the connecting cord burns through.

10:49am: Gagarin ejects at 7km altitude and begins parachuting to the ground.

10:55am: The spacecraft lands, slowed by its own parachute.

10:57am: Gagarin lands 3km from the spacecraft and is greeted by the local workers.

ILLUSTRATION

▼ **Hero's welcome: Yuri Gagarin rides with Soviet premier Nikita Khrushchev through Moscow, on 14 April 1961**

Where to stargaze in ENGLAND

England's dark-sky sites make it a great place for astronomy, provided you know where to go. **Jamie Carter** recommends the best locations

National treasures: get to know England's finest dark-sky sites

Jamie Carter is a science and astronomy writer and author of *A Stargazing Program for Beginners: A Pocket Field Guide*

While it's often considered a densely populated and light-polluted urban country that's not ideal for amateur astronomy, England has plenty of hills, open moorland, reservoirs and remote countryside that are perfect for stargazing away from the glow of towns and cities.

Dark-sky locations in Scotland and Wales are high on amateur astronomers' bucket lists, yet there are many International Dark Sky Reserves in England where darkness is protected, including Exmoor National Park, Moore's Reserve in the South Downs National Park, Cranborne Chase and the newly-certified Yorkshire Dales and North York Moors National Parks. There are also two International Dark Sky Parks celebrated for having the very darkest skies: Bodmin Moor Dark Sky Landscape in Cornwall and Northumberland National Park and Kielder Water & Forest Park.

As well as a mushrooming of areas certified by the International Dark-Sky Association (IDA), England also boasts a variety of Dark Sky Discovery Sites (**www.darkskydiscovery.org.uk**), mostly nominated by local astronomy groups. Selected for their ease of accessibility, these areas are super-dark, offering incredible views of starry night skies.

We've also uncovered four other English regions that haven't yet been officially designated as having dark skies, but it's only a matter of time. The Cotswolds, the Forest of Dean and the Wye Valley, the Norfolk Coast and the Peak District National Park all richly deserve a visit by anyone looking for starry skies. So read up on the Countryside Code, check current COVID-19 guidance, don your warm clothing and sensible shoes, and get ready to discover England's dark side.

1. Yorkshire Dales & North York Moors National Parks, Yorkshire

Welcome to the UK's largest Dark Sky Reserve. Either side of the A1(M) in northern England, the Yorkshire Dales and North York Moors were designated Dark Sky Parks in December 2020, and together their combined area of over 3,500km^2 makes them one of the largest spaces with a protected night sky in Europe. The North York Moors has three Dark Sky Discovery Sites: the Moors National Park Centre at Danby, Sutton Bank and Dalby Forest. Meanwhile, the Yorkshire Dales has seven Dark Sky Discovery Sites, with the original three at Hawes, Malham and Buckden now added to by four new sites within the Nidderdale Area of Outstanding Natural Beauty (AONB) west of Ripon and northwest of Harrogate. Stargazers in this area of reservoirs, open heather moorland and eye-catching rock formations should head to Scar House, Thruscross Reservoir, Fewston Reservoir and Toft Gate Lime Kiln. A joint Dark Skies Festival is held regularly by both national parks every February.

www.yorkshiredales.org.uk, www.northyorkmoors.org.uk ▸

OLIVER HERBOLD, MATT GIBSON YDNP

Natural beauty: a stunning view of the Milky Way from Norber Ridge in the Yorkshire Dales National Park

Coastal colours: the greens of an aurora blend in with the night sky in this view from Norfolk's Morston Quay

2. Norfolk Coast AONB, Norfolk

Those after naturally dark landscapes should consider visiting the Norfolk Coast and Norfolk Broads, which together form one of the UK's darkest places. A site that's perhaps best known to amateur astronomers is Kelling Heath Holiday Park near Holt in the Norfolk Coast Area of Outstanding Natural Beauty (AONB), which is the location of twice-yearly star parties. It's also one of the area's four 'Milky Way-class' Dark Sky Discovery Sites, meaning the Milky Way is visible in the night sky with the naked eye. The other three are Wiveton Downs Nature Reserve, RSPB Titchwell Marsh Nature Reserve and nearby Barrow Common near Brancaster.

Local astronomy groups – the North Norfolk Astronomy Society and the Kings Lynn and District Astronomy Society – host stargazing events over the year. The third Norfolk Coast Dark Skies Festival is planned for 25 September to 10 October 2021.
www.visitnorthnorfolk.com/see-and-do/dark_skies.aspx

3. Peak District National Park, northern England

A vast area of upland at the southern end of the Pennines between Manchester and Sheffield, the Peak District is the UK's original national park. Together with Nottingham Trent University and the Science and Technology Facilities Council, the park authorities have identified three Dark Sky Discovery Sites ideal for stargazing and kitted them out with interpretation panels that change with the seasons, showing visitors what constellations are visible in the night sky.

Combining dark skies and panoramic views, they include the 'Milky Way-class' Surprise View near Hathersage, overlooking the Hope Valley, Parsley Hay car park (SK17 0DG) near Arbor Low stone circle, and Minninglow car park (DE4 2PN).
www.peakdistrict.gov.uk/darkskies

Looking north: the Peak District's Ramshaw Rocks make a striking foreground for a composite image of star trails around Polaris

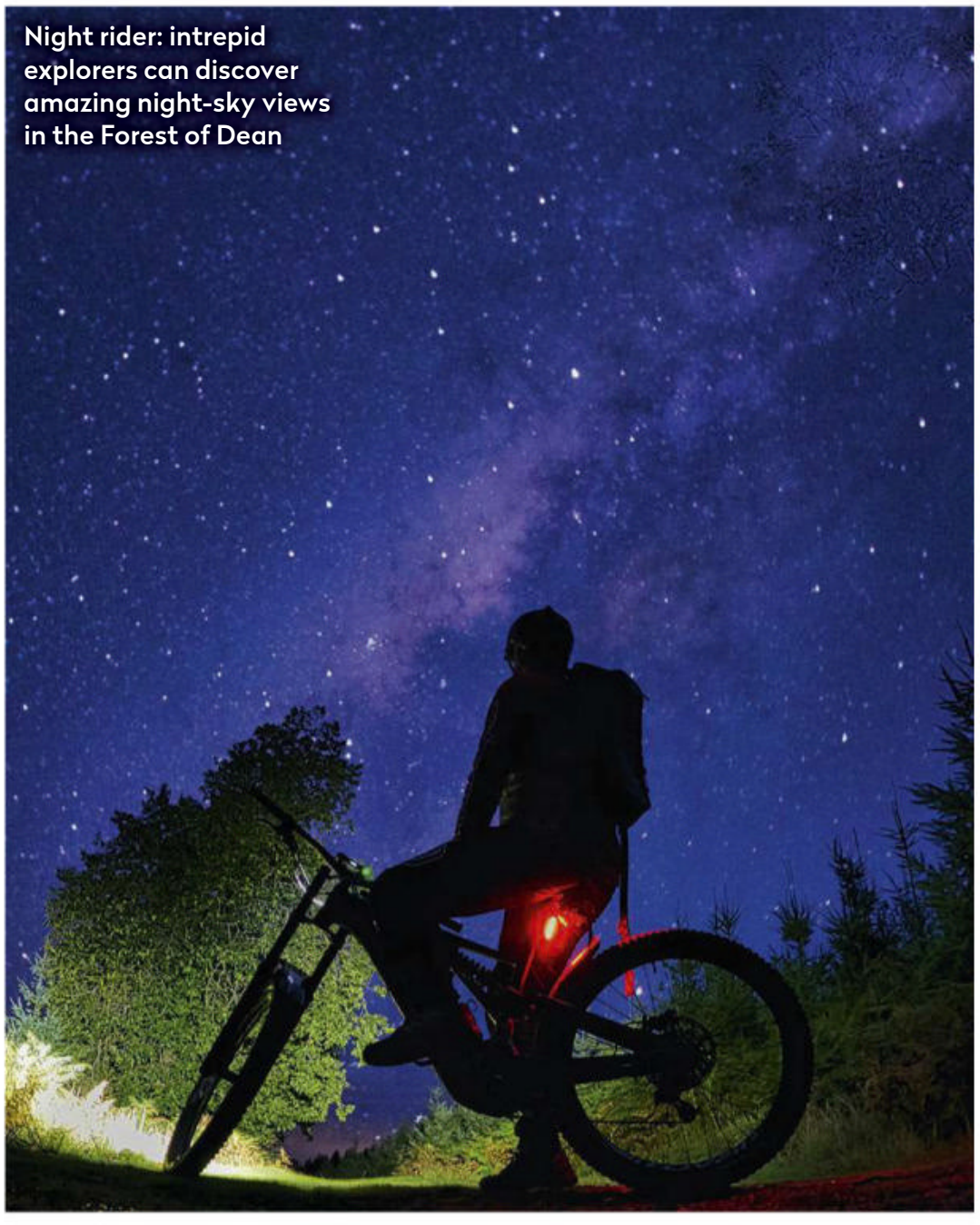
4. Cotswolds AONB, Gloucestershire and Oxfordshire

An Area of Outstanding Natural Beauty (AONB) since 1966, the rolling hills and grasslands of the Cotswolds make is one of the best places to go stargazing in south central England. It's got two Dark Sky Discovery Sites, both 'Milky Way class', at Aunt Phoebe's Recreation Ground in the village of Long Compton, and at the Rollright Stones ancient monument slightly further south towards Chipping Norton.

The latter is a regular observing venue for the Chipping Norton Amateur Astronomy Group (CNAAG) and easily accessible at night. To the southwest, the area around the villages of Northleach and Guiting Power offers dark skies that are ideal for seeing the Milky Way, while Cleeve Hill above Cheltenham is a good place for stargazing, despite being close to a town.

www.cotswoldsaonb.org.uk

Easy to get to: although Cleeve Hill is close to Cheltenham, it offers spectacular views for stargazers



Night rider: intrepid explorers can discover amazing night-sky views in the Forest of Dean

5. Forest of Dean and Wye Valley, Gloucestershire

Anywhere away from towns and villages in the Forest of Dean and Wye Valley region will put you under a dark sky. A great place to start is the iconic Symonds Yat Rock viewpoint. It offers a jaw-dropping panorama over a bend in the River Wye and from March to May it's possible for astrophotographers to create a panorama with the full arch of the Milky Way spanning over it.

Similarly, Bigsweir Bridge near St Briavels can create a great foreground for long exposure photographs. Other locations stargazers should consider in the area include the wide-open sky of Cannop Ponds, Mallards Pike Lake and Speech House Lake in the Forest of Dean.

Intrepid night-hikers who are after spectacular vistas should consider the Devil's Pulpit along the Wye Valley Walk for views over Tintern Abbey, and May Hill near Gloucester – one of the highest points in the Forest of Dean – for its 360˚ views.

www.visitdeanwye.co.uk ▸

JAMES ROWLEY-HILL, MATT_GIBSON/ISTOCK/GETTY IMAGES, BEN HIRST, PAUL WHITE

High rise: at 519m, Dunkery Beacon is the highest point on Exmoor, making it a wonderful location for observing

6. Exmoor National Park, Somerset and North Devon

Celebrating its 10th anniversary as a Dark Sky Reserve this year, Exmoor National Park has some of the darkest skies in the country. As a holiday area it's also got plenty of accommodation, so you can easily visit the area with your family and take in the night sky. There are lots of iconic and easily accessible places to aim for, including the highest point on Exmoor, Dunkery Beacon. Also worth a night-time trip is Heddon's Mouth, a spectacular rocky cove on the coast of North Devon where the River Heddon tips into the ocean. There's a car park, a circular walk and accommodation (The Hunter's Inn pub). Other dark-sky sites include; Holdstone Hill, County Gate, Brendon Two Gates, Webbers Post, Anstey Gate, Haddon Hill and Wimbleball Lake.

Exmoor National Park Authority has just produced a free downloadable *Astronomer's Guide to Exmoor* booklet – complete with dark-sky meter readings – and it's developing a Dark Sky Discovery Trail over farmland for 360° views. Exmoor Dark Skies Festival takes place every October. **www.exmoor-nationalpark.gov.uk/enjoying/stargazing**

KEITH TRUEMAN, PAUL HOWELL, LES HUNT

Ancient setting: the ruin of Knowlton Church in Dorset makes an impressive foreground for astrophotography

7. Cranborne Chase AONB, Wiltshire, Dorset, Hampshire and Somerset

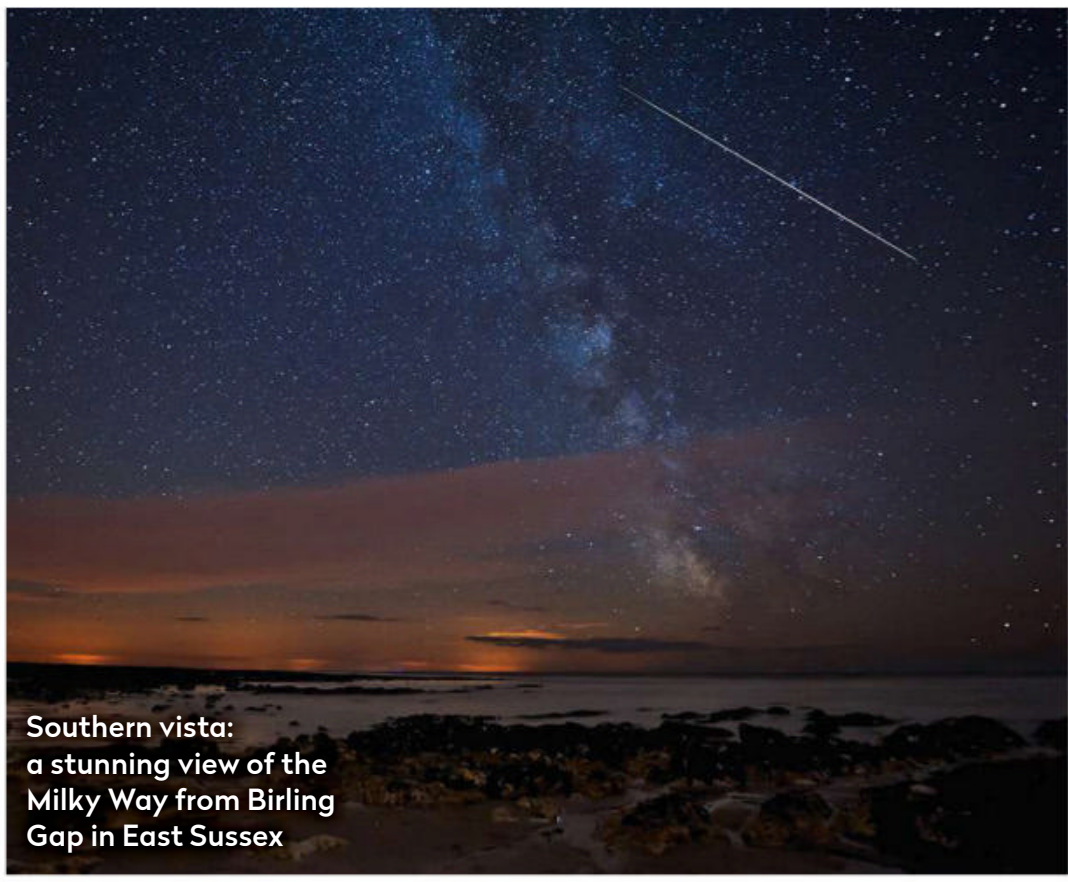
Star-chasing is easy in the Cranborne Chase Area of Outstanding Natural Beauty (AONB) between Warminster, Salisbury and Bournemouth. A chalk plateau in southern England overlapping the boundaries of Wiltshire, Dorset, Hampshire and Somerset, it's been a Dark Sky Reserve since 2019. The best places to stargaze in its 980km^2 have been selected by Dark Skies advisor Stephen Tonkin, author of our monthly 'Binocular Tour' (see page 64). In the south, close to Bournemouth, is Badbury Rings, an Iron Age hill fort, while nearby is Knowlton's fabulous Church Henge – the ruins of a medieval church surrounded by prehistoric barrows and stones – which makes for an iconic astrophotography foreground. Another target for nightscape photographers should be King Alfred's Tower near Bruton in Somerset, a high folly from 1772, while in the AONB's dark centre is Win Green, its highest point and a Site of Special Scientific Interest. **https://cranbornechase.org.uk**

8. Moore's Reserve, South Downs National Park, Hampshire, West Sussex and East Sussex

Named in honour of the late presenter of *The Sky at Night*, Sir Patrick Moore, who lived in Selsey, West Sussex, this Dark Sky Reserve is also England's newest National Park. An area of chalk downland protected since 2011, the South Downs National Park stretches from St Catherine's Hill near Winchester, Hampshire in the west to Beachy Head, East Sussex in the east. An important corridor of darkness just under 100km from London, the darkest cores are in the west of the park with Dark Sky Discovery Sites at Butser Hill, Buriton recreation ground, Harting Down, Iping Common and Bignor Hill. There are more along the coast including Chidham and West Itchenor near Chichester Harbour, and Birling Gap, near the Seven Sisters chalk cliffs near Seaford.

If the weather isn't looking good consider a visit to the South Downs Planetarium and Science Centre near Chichester, where Professor John Mason conducts lively tours of the night sky from inside. The South Downs National Park stages a Dark Skies Festival each February.

www.southdowns.gov.uk



Southern vista: a stunning view of the Milky Way from Birling Gap in East Sussex

England's dark-sky locations

Discover your nearest English dark-sky site with our map showing where to find the country's best places for stargazing

1 Yorkshire Dales & North York Moors National Parks, Yorkshire
Area 2,179km² • 1,436km²
Event Dark Skies Festival (Feb)

2 Norfolk Coast Area of Outstanding Natural Beauty (AONB), Norfolk
Area 450km² • Event Dark Skies Festival (Sep)

3 Peak District National Park, northern England
Area 1,4374km² • Event Guided Stargazing tours

4 Cotswolds AONB, Gloucestershire and Oxfordshire
Area 2,038km² • Event Chipping Norton Amateur Astronomy Group activities

5 Forest of Dean and Wye Valley, Gloucestershire
Area 328km² • Event Night-trek observing

6 Exmoor National Park, Somerset and North Devon
Area 181km² • Event Dark Skies Festival (Oct)

7 Cranborne Chase AONB, Wiltshire, Dorset, Hampshire and Somerset
Area 980km² • Event Dark Skies Festival (Feb)

8 Moore's Reserve, South Downs National Park, Hampshire, West Sussex and East Sussex
Area 1,627km² • Event Dark Skies Festival (Feb)

The fundamentals of astronomy for beginners

EXPLAINER

What is a ‘supermoon’ and when do they occur?

Jenny Winder investigates the facts and fiction behind the term

PAUL GILLIS/ALAMY STOCK PHOTO

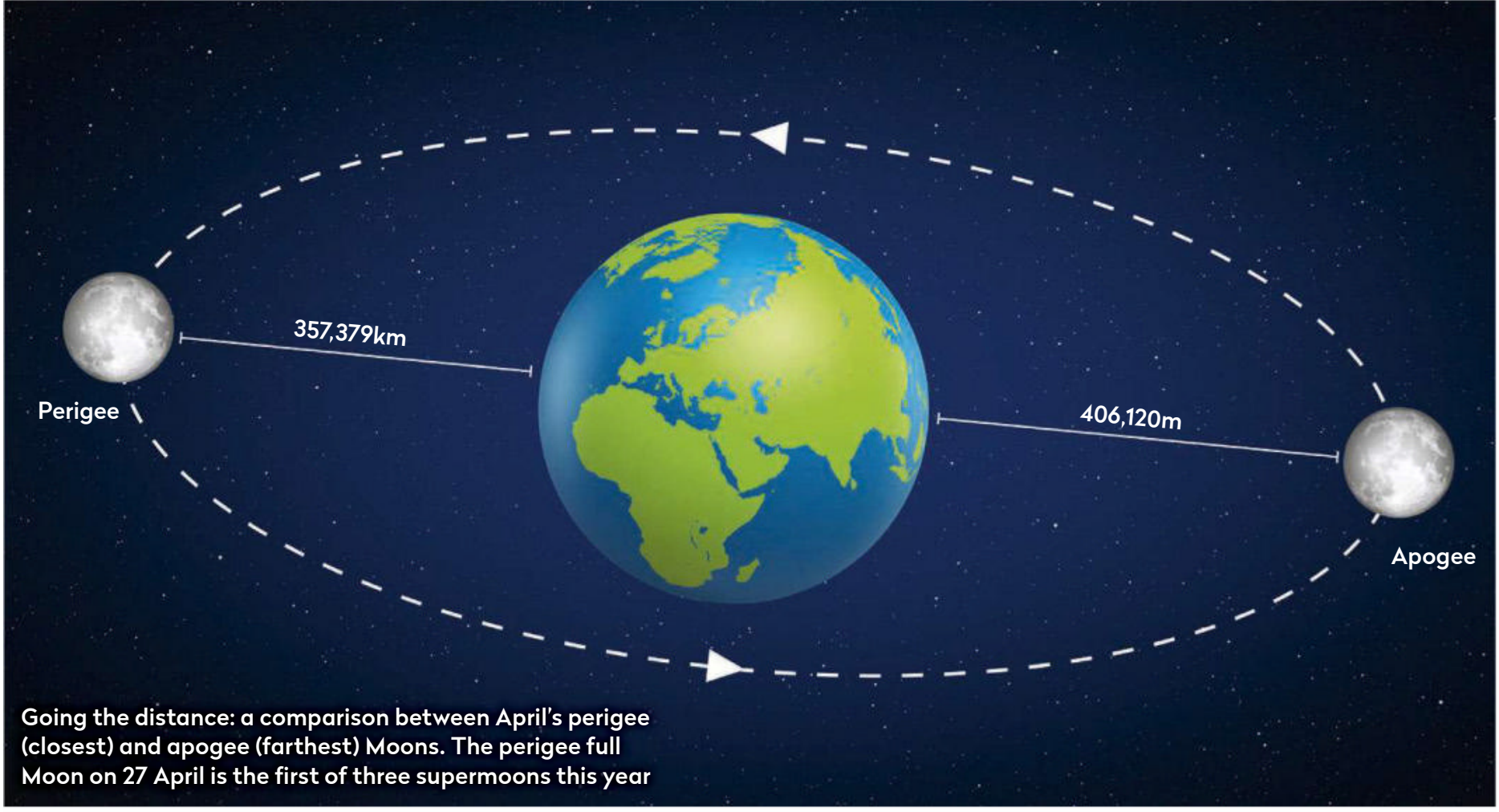
April will see the first of three consecutive supermoons in 2021, making this an ideal time to discuss this often-misunderstood phenomenon and to separate the facts from the fiction. A supermoon occurs whenever a full Moon coincides with the Moon’s closest approach to Earth along its orbit. The Moon takes just over 27 days to orbit Earth on an elliptical path that takes it from its most distant point from Earth at apogee, to its closest approach at perigee. These distances can vary between 406,712km (apogee) and 356,445km (perigee). It also takes just over 29 days to cycle from one full Moon to the next. Meanwhile, Earth takes 365 days to orbit the Sun and this means it takes 14 lunar cycles (411 days) to go from one full perigee Moon to the next one.

▲ Super-sized: on 31 January 2018 we were treated not only to a supermoon, but also a lunar eclipse. This dramatic image was taken in Somerset

The term supermoon refers to both perigee full and new Moons but, as the new Moon is not visible we will concentrate on the full supermoon. We get 12 or 13 full Moons each year but, due to the orientation of the Moon’s orbit, not every full Moon is a supermoon, in the same way that not every full Moon is a lunar eclipse.

Origins of the name

The name ‘supermoon’ was first coined by astrologer Richard Nolle in 1979. He defined it as “a new or full Moon that occurs when the Moon is at or near (within 90 per cent of) its closest approach to Earth in its orbit”. Astronomers prefer the more precise, though perhaps less catchy, term of a perigee full Moon to describe a full Moon that occurs when the Moon’s centre is less than 360,000km from the centre of Earth; or a perigee syzygy full Moon, where syzygy

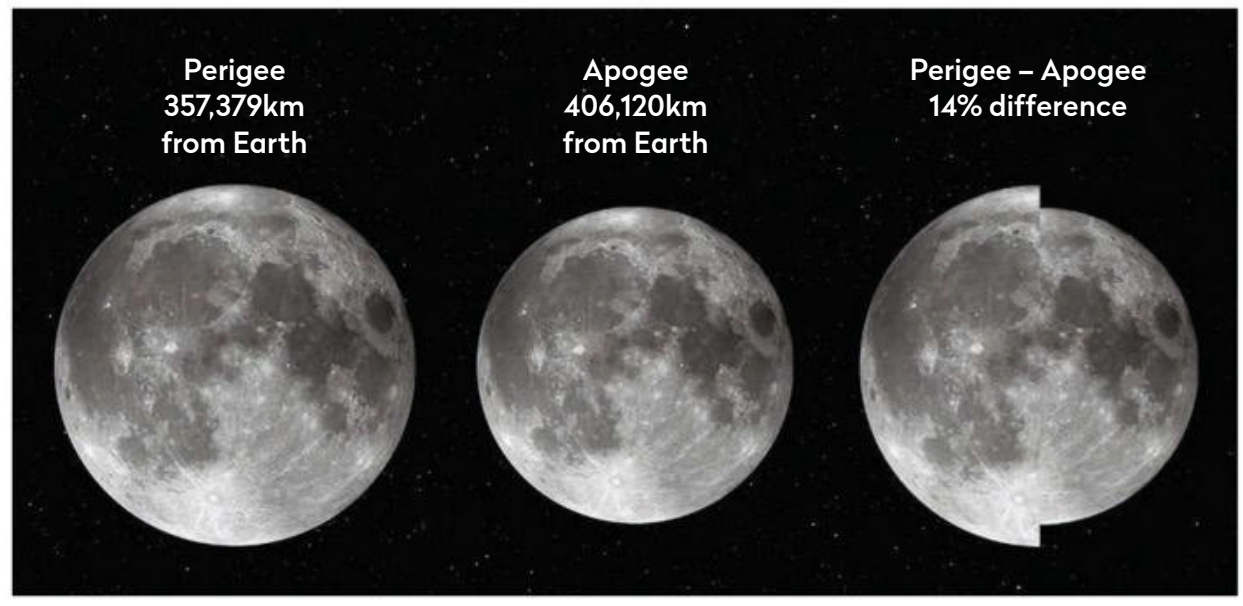


Going the distance: a comparison between April's perigee (closest) and apogee (farthest) Moons. The perigee full Moon on 27 April is the first of three supermoons this year

refers to a straight-line configuration of three or more celestial bodies in a gravitational system (in this case Earth, the Moon and the Sun). The opposite phenomenon, an apogee syzygy full Moon, is similarly dubbed a 'micromoon'.

Each full Moon has been given a name by various cultures over time so, on Monday 27 April we will see the 'Super Pink Moon', followed on Wednesday 26 May by the 'Super Flower Moon', which will also be a 'Blood Moon' due to a lunar eclipse for observers in Australia, western America and Southeast Asia. Then, on 24 June, the 'Super Strawberry Moon' will appear.

Much has been written about supermoons 'stunning' and 'dazzling' observers, and this is another reason some astronomers balk at the term. In reality, a full Moon at perigee appears only 14 per cent larger due to being closer to us, and only 30 per cent brighter than an apogee full Moon. A supermoon is also only about 7 per cent larger and 15 per cent brighter than an average full Moon. Without a side-by-side comparison, it is difficult to spot the difference from one month to the next. The difference in brightness is due to the reflected light from the lunar surface that reaches Earth being inversely proportional to the square of the distance between them.



▲ On view: the difference in apparent size between April's apogee and perigee full Moons

Jenny Winder is a freelance science writer, astronomer and broadcaster

Claims that the Moon appears larger than this are likely to be due to the 'Moon illusion'; indeed, the Moon does appear much larger when observed near the horizon at moonrise and moonset. The reason for this optical illusion is still under debate, but is likely to do with the way our brains process objects close to the horizon as being larger when in proximity to buildings and trees, than when they are high in the sky with nothing to compare sizes against.

There is also scant scientific evidence to support claims that supermoons cause earthquakes, volcanic eruptions, extreme weather and tsunamis, or floods and pestilence! The Moon is, of course, the driving force for Earth's tides: full and new Moons are when the Earth, Sun and Moon line up to produce extreme spring tides, but the effect of perigean spring tides only increases the tidal variations by about 5cm on average. In recent years there have indeed been a handful of tsunamis and earthquakes that coincided with a supermoon but, with around three supermoons every 14 months it would be unusual if such a disaster did not coincide with a supermoon now and then.

A supermoon may not be so 'super', or even rare, but once you cut through the hype, it is still a great way to engage with our nearest neighbour.

Do supermoons always come in threes?

Like buses, perigee full moons often arrive all at once

This month brings the first of three consecutive supermoons in 2021, but this is not unusual. Indeed, every 14 lunar months the series of full Moons cycles from largest to smallest and back again as the Moon orbits Earth. Perigee can last between two and five full Moons. For a full Moon to be classed as 'super' it must occur when it is around 360,000km away from Earth or less, so the full Moons occurring either side commonly also fall within the supermoon category. On rare occasions we get two or four supermoons in a row, but three is the most common.

Make a simple dew heater for your camera lens

Give your camera year-round protection from unwanted water vapour and get clearer images

Keep it simple: a home-made dew heater reduces the need for cables and batteries

Astrophotography and nightscape photography often require long imaging sessions, and with that comes a risk of your lens dewing up. If the temperature of the glass on the front of the camera lens cools to a few degrees below the dew point, then water vapour in the air will begin to condense onto the glass, causing the lens to become misted over. Any subsequent images that are taken through the lens will be useless. People often think this is only an issue during winter, but because the dew point is related to humidity levels, lenses can fog or dew up even more rapidly on a warm and humid summer evening.

Preventing problems

Keeping the lens glass warmer than the dew point will prevent it from fogging up, and a simple way to achieve this is to use a dew heater. You can buy them commercially, but they are usually powered from a rechargeable power tank that can be heavy to carry around, particularly if you are shooting on location. You can buy dew bands that run from 9V batteries, but they consume plenty of power so the batteries don't last very long. In addition to worrying about batteries, you also have the inconvenience of dealing with a set of cables from the dew heater to the controller and power supply.

ALL PICTURES: MARY MCINTYRE

Mary McIntyre is an outreach astronomer and astro imager based in Oxfordshire

One way to solve these issues is to make a simple dew heater that uses hand warmers as its heat source. For this project we used inexpensive reusable hand warmers, which can be purchased online. They are filled with a liquid that turns into a solid once activated. This process is an exothermic reaction so they remain warm for a couple of hours after activation. Once they have cooled again, you can reverse the reaction by warming them in a pan of hot water; they can then be reused again and again.

Our dew heater consists of a dew band made from a sock to hold the hand warmers, which is held in place with Velcro; the fastening is adjustable so it can fit a variety of different camera lens sizes and can even be adapted to fit around a small refractor telescope. If you are doing a long imaging session, you can easily remove the dew heater and swap the hand warmers for a fresh pair between shots.

There is no temperature control with this simple solution, so there is a small chance that the heat may cause a slight increase in dark signal noise (unwanted artefacts) in your images. However, the dew heater will be placed around the camera lens rather than near the camera sensor, so it shouldn't affect the images too badly. If it does cause a bit more noise, it is still far more successful to carry out a noise reduction step in post-processing than it is to try and gain any useful data from images taken through a fogged-up lens. The added bonus of its portability coupled with no cable management definitely make up for this.

What you'll need

- Two small reusable hand warmers – the ones we used measured 9cm x 5.5cm. These can be purchased from many sources online.
- A thermal sock that's wide enough to hold the hand warmers and long enough to fit around your camera lenses.
- A sewing machine (optional), needle and thread. Two buttons (we used ones that were 2.2cm in diameter), and two pieces of elastic, about 4cm long; we used 0.5cm-wide elastic, but any pieces will do.
- Two strips of Velcro; we used 5cm of loops and 11cm of hooks. This allows you to fit the dew heater around different sized lenses. (If you don't have any Velcro you can thread shoelaces into small holes at each end, then tie them together to secure the dew heater in place.)

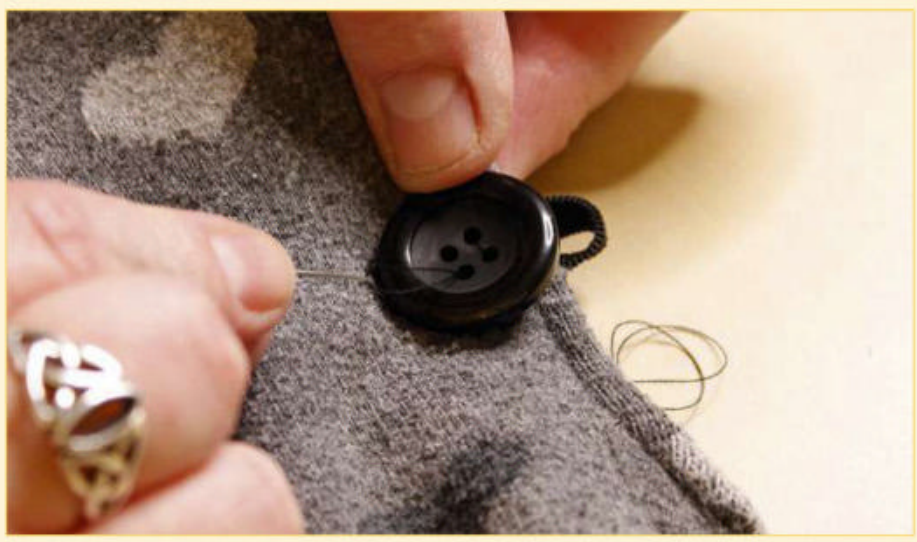
Step by step

Step 1

Lay the sock flat on your table and then cut two slits that are a bit smaller than the long edge of the hand warmers into one edge. The slits will stretch a bit during Step 2 so don't make them too big.

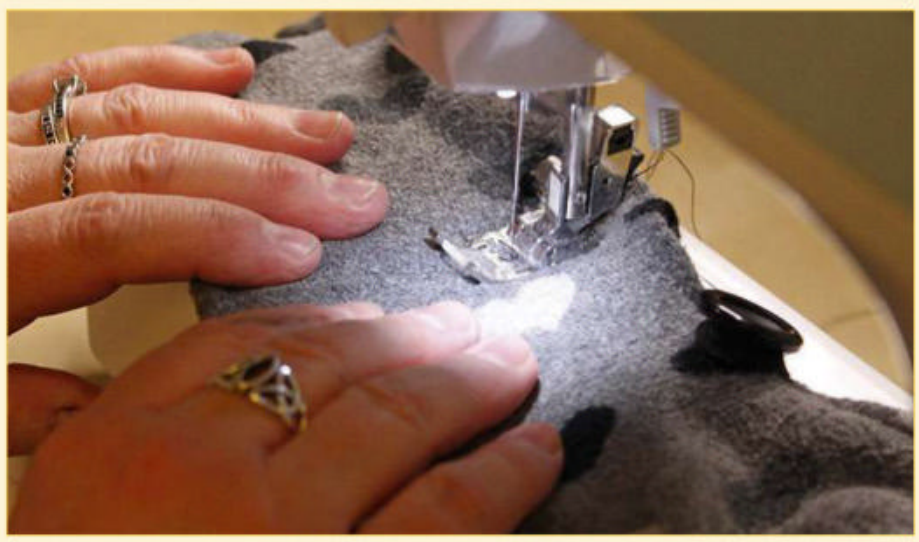
Step 2

Sew a basting stitch around the edges of the slits to prevent fraying, then fold the edge inwards and sew it down with a straight stitch to produce a neat edge. We used a sewing machine, but this can be done by hand if you don't have one.



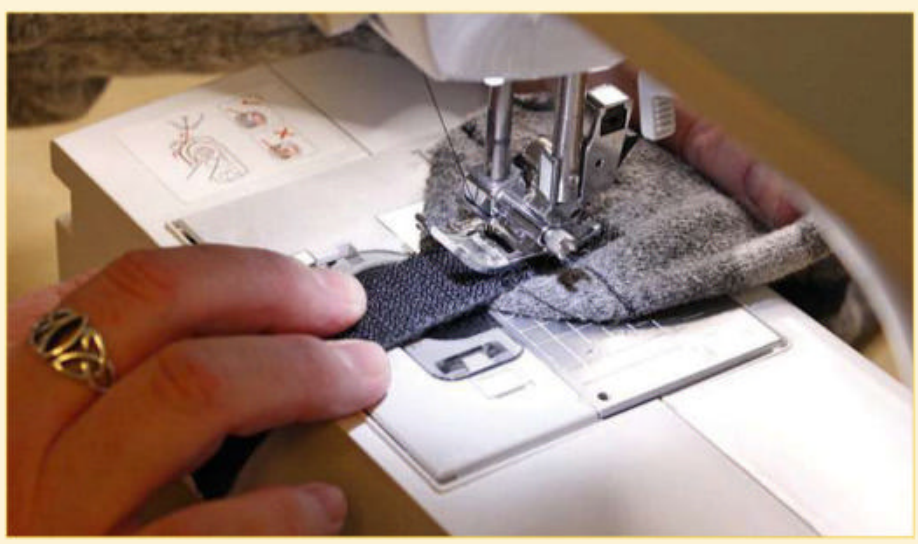
Step 3

Sew a button onto the middle front edge of both slits and then sew loops of elastic onto the back edges so they line up with the buttons. Once done up, this will keep the hand warmers in place and prevent them from falling out.



Step 4

Sew a seam across the cuff and toe of the sock, and also across the middle (roughly where the heel is) to form two enclosed pockets. This is where the hand warmers will be fitted. We used a sewing machine here (and Step 5) but a needle and thread is fine.



Step 5

Next, sew the 5cm strip of Velcro (loops up) to the outside of the one end of the sock, then sew the 11cm strip (hooks up) to the inside of the other end, leaving a piece hanging over the edge. Fastening this will keep the heater attached to the lens.

Step 6

Activate the two hand warmers, pop them into the pockets and fasten the buttons. You can now wrap the dew heater around your camera lens and secure it with the Velcro. Be careful to avoid part of the sock covering the lens as you don't want sock vignetting!

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

CAUTION
Never observe or image the Sun with the naked eye or any unfiltered optical instrument

Catch the Sun's prominences

Use a solar hydrogen-alpha filter to safely capture the dramatic arches of light

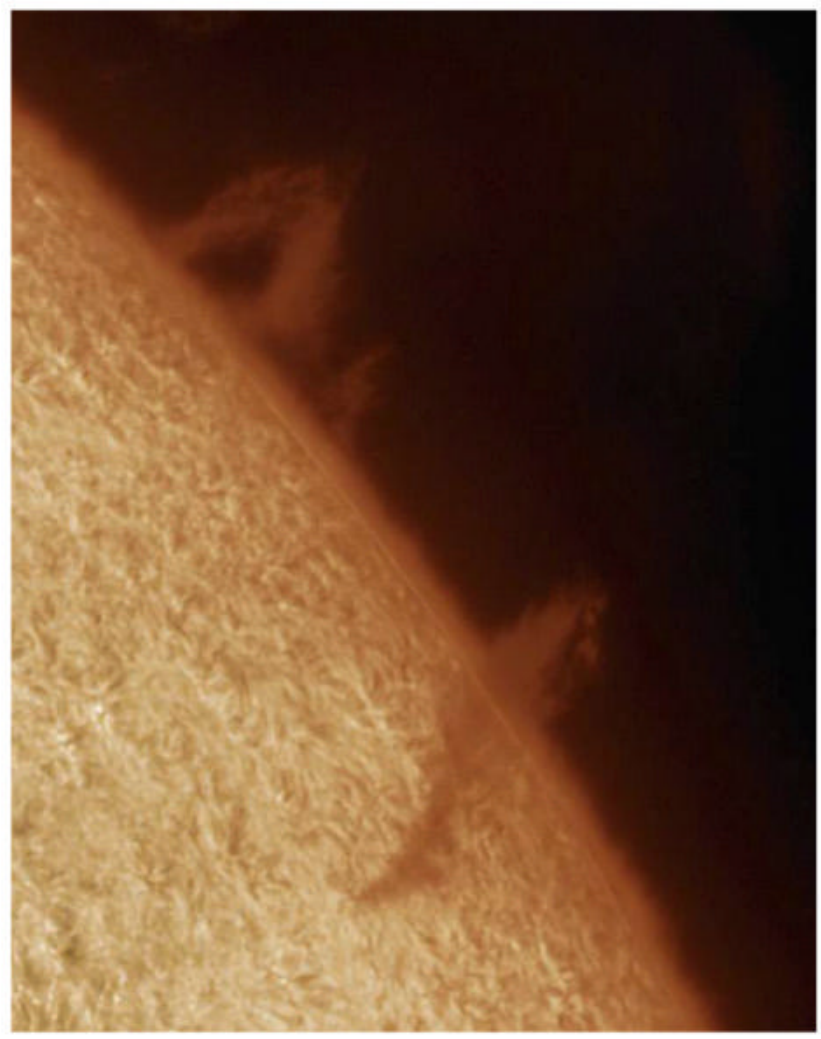
The Sun may or may not be waking up after a long slumber but one solar phenomenon which continues to impress, even through periods of low solar activity, are prominences. In order to see or image prominences you'll need a hydrogen-alpha (h-alpha) filter designed for solar work. (Note that deep-sky h-alpha filters are unsafe for viewing the Sun.)

Viewing the Sun through a solar h-alpha filter removes all wavelengths except those centred on 656.28nm, the primary emission or absorption line of hydrogen in the visual part of the spectrum. You'll see the Sun as it appears courtesy of hydrogen plasma; contorted by concentrated magnetic fields, this produces a view of our nearest star that is altogether different to the view through a white light filter.

The 'surface' of the Sun visible through a white light filter is known as the photosphere, or 'sphere of light'. Through an h-alpha filter the photosphere is covered by a blanket of hydrogen, forming what is called the chromosphere, or 'sphere of colour'. It gets this name from the fleeting glimpse of it we get just before and after totality during a total eclipse of the Sun. At such times it appears as an intensely red-pink arc.

Twists and turns

Active sunspot regions look amazing through an h-alpha filter. The strong magnetic field lines which permeate such regions are revealed by hydrogen plasma, allowing you to see them twist and turn through the region. In addition, clouds of cooler hydrogen plasma float above the chromosphere, appearing dark against its mottled 'surface'.



▲ Light show: prominences range in size, up to a significant proportion of the Sun's disc

These are filaments, another phenomenon associated with the Sun's magnetic field. They are seen snaking across the chromosphere, the largest being longer than the Earth – Moon distance!

As the Sun turns on its axis, taking 25 days at the equator, but 35 days at the poles, from Earth it appears to drag the filaments into view around the eastern limb, or rotate them out of view around the western limb. At the limb, the material forming the filament that's elevated above the chromosphere appears to extend away from the Sun's edge. This is what's known as a prominence. Manipulated by the Sun's magnetic field, prominences range in size from 'small' tufts up to arches of light measuring a significant proportion of the size of the Sun's disc, from several tens of thousands to hundreds of thousand kilometres.

Prominence imaging needs special techniques; as they appear fainter than the chromosphere, boosting camera sensitivity to achieve the right prominence exposure typically burns out the Sun's surface.

Separate prominence and surface images can be composed to form a single image. Alternatively, the surface can be masked out to simulate an artificial eclipse. The real holy grail is getting the surface and prominence imaged at the same time and this is the subject of our step-by-step guide opposite.

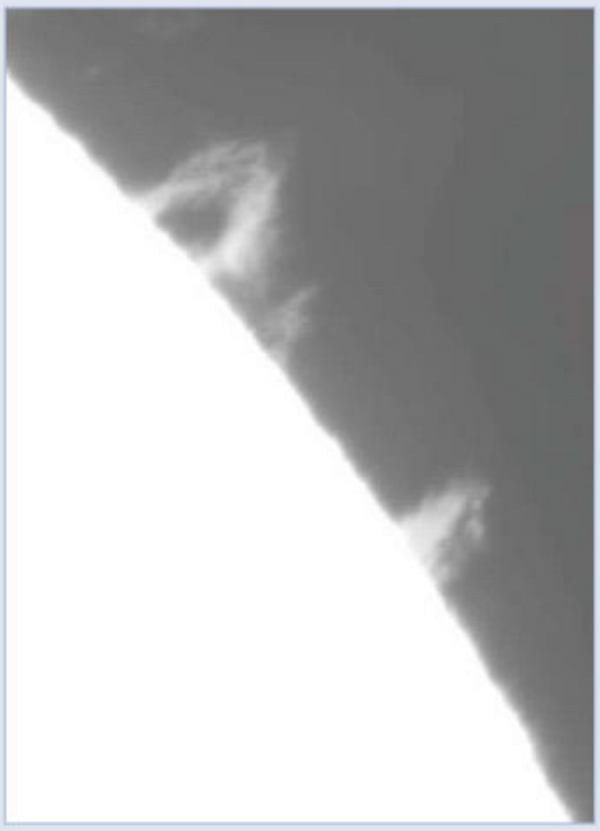
Recommended equipment: h-alpha filtered solar telescope, high-frame rate mono imaging camera

Pete Lawrence is an expert astro imager and a presenter on *The Sky at Night*

✉ Send your images to:
gallery@skyatnightmagazine.com

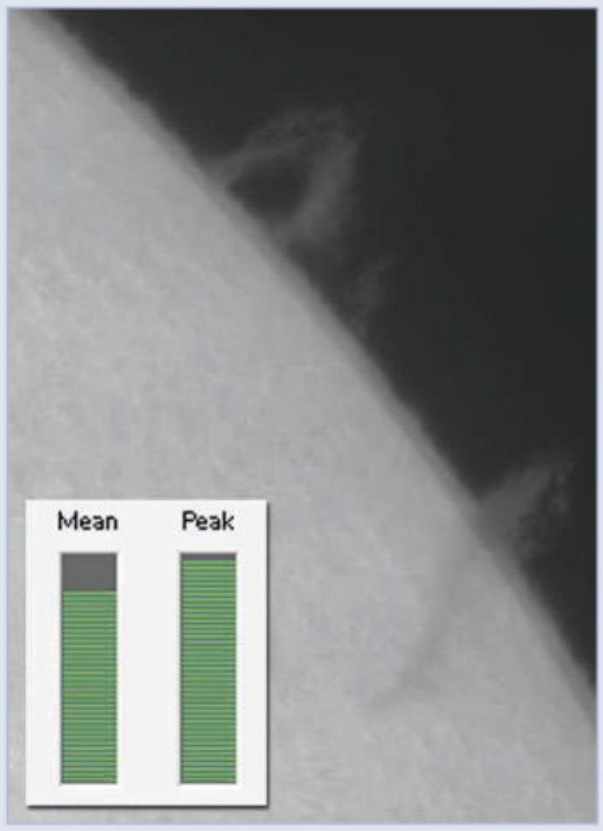
ALL PICTURES: PETE LAWRENCE

Step by step



STEP 1

Using a correctly configured hydrogen-alpha imaging setup, adjust settings to overexpose the chromosphere to white. Gamma should be set to zero or slightly higher (lower contrast). Slew around the Sun's edge looking for a suitable prominence. Once found, frame your shot to include the prominence and some of the chromospheric surface.

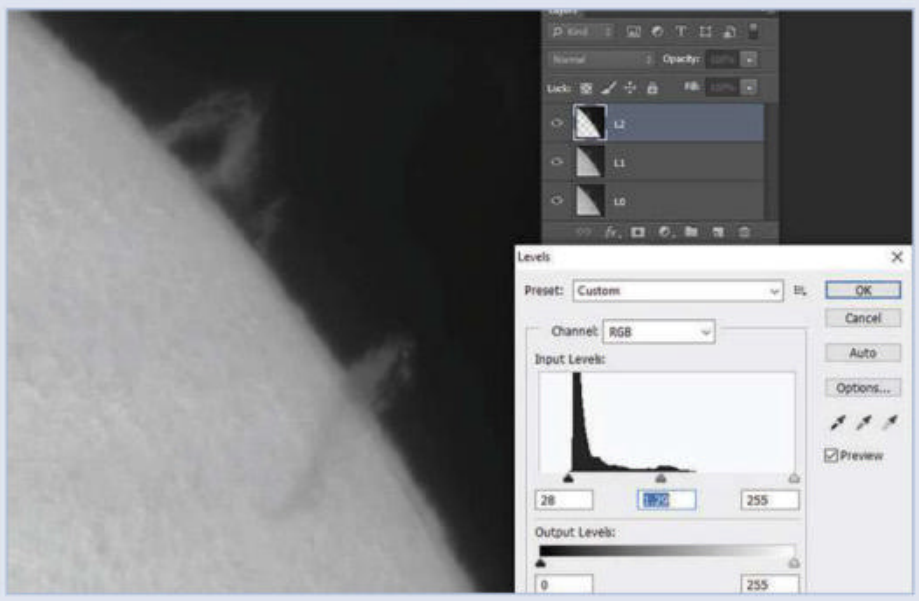


STEP 2

Adjust camera gain setting, monitoring the 'Peak' level indicator. Most control programs show this information numerically or with a levels bar. Set the level close to 'Peak', but don't exceed it. Then make your capture. Keep capture times shorter than 30" to avoid motion blur on active prominences; longer times can be used for ones that appear to be fairly static.

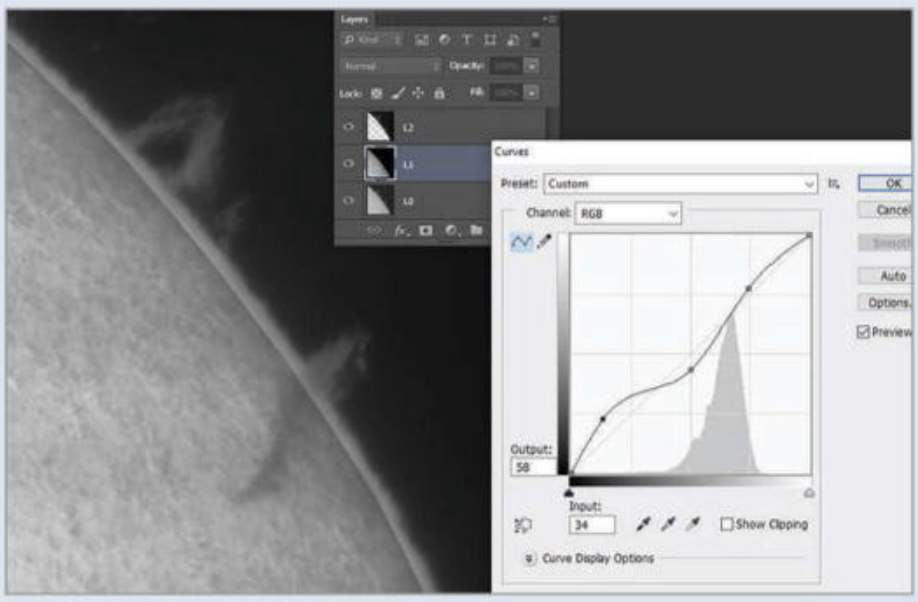
STEP 3

Process your capture result in a registration/stacking program such as AutoStakkert! Ensure only the target is selected when setting alignment points (APs) – ie if you use the automatic alignment point option, ensure the threshold doesn't also select the sky. If you are struggling, switch to manual and do it by hand.



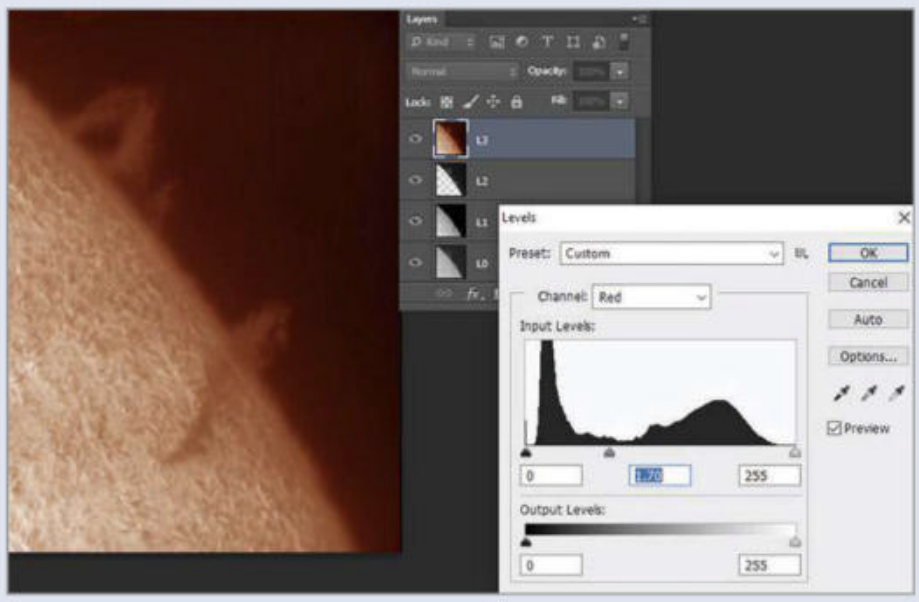
STEP 4

Open the processed image in photo-editing software. Duplicate layer 0 (L0) twice (as L1 and L2). In the upper layer (L2), select the line between the chromosphere and spicule layer, and expand it to cover the prominence. Apply a 4-pixel feather; invert selection (to select over-exposed chromosphere), then delete and deselect.



STEP 5

Select L1 (chromosphere) and using levels, curves, brightness and contrast, adjust to bring out chromospheric detail to taste. Adjust so the interface between L2 and L1 looks fairly natural. If necessary, adjust L2's levels to improve the join. It may take a few goes at adjusting L1 and L2 to get the composite looking right.



STEP 6

Once happy with the join, duplicate L1 and L2 and flatten them into a single layer (L3), then save the file. To apply RGB colour, select L3 and open the levels tool. Select the R channel and drag the mid-point towards the black point. Then repeat with G and B, dragging both channels' mid-points towards white instead.

Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

Boost the contrast in your astrophotos

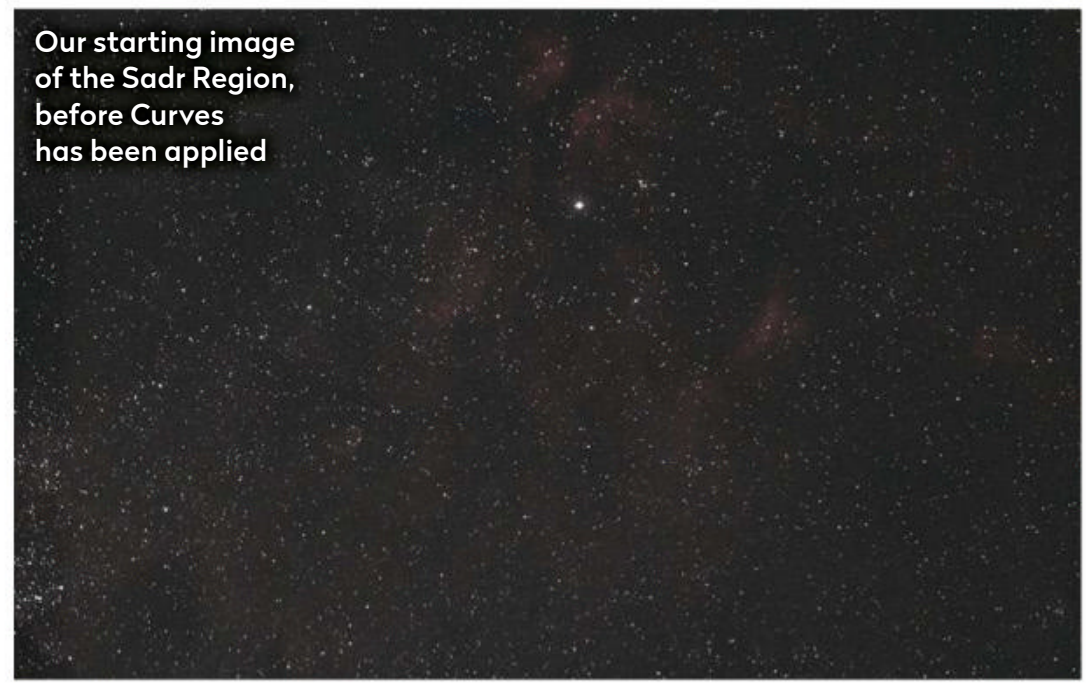
Using Curves to bring out light and dark and mid-tone areas across your images

Astrophotography processing is about bringing out details by stretching data. This is achieved via two main editing functions: 'Levels' and 'Curves'. Both are available in Adobe Photoshop and the free editing software GIMP, and it's often necessary to perform a Levels adjustment before using Curves.

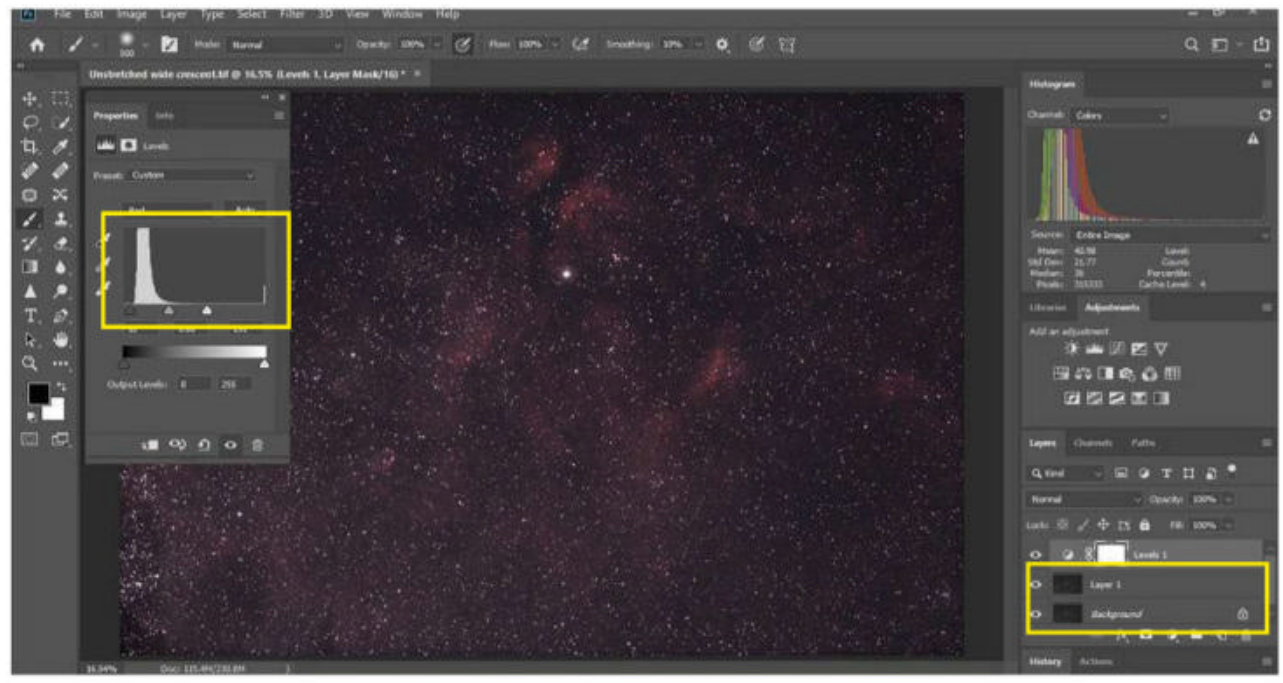
Levels is used to balance the 'Red', 'Green' and 'Blue' (RGB) channels; this process draws out detail by brightening the image. Using Curves then manipulates the tones in your image, allowing greater contrast between light, dark and mid-tone areas. To demonstrate how the Levels function can be applied, we are using Photoshop to process a wide-field image of the Sadr Region, an emission nebula (see right).

We start with a TIFF file that comprises five hours of data taken with a DSLR camera and then stacked in DeepSkyStacker. After uploading in Photoshop ('File > Open > Filename') we click 'View > Fit on Screen' and the image fills the main window. Ensure the histogram on the right-hand side is set to 'Colours'. At the start of the process the histogram is thin; by stretching the data we will widen this histogram.

We wish to create a layer that duplicates the base layer but won't overwrite it. This is done by holding down the 'Shift, Ctrl, Alt, N and E' keys simultaneously and 'Layer 1' appears above our background layer (see Screenshot 1). Do this each time we wish to make a new adjustment. Next, click 'Image > Adjustments > Levels'. Starting with the 'Red' colour channel (Screenshot 1) we drag the right-most tab under the histogram towards the curve as indicated. If the left-most tab is not touching the left edge of the curve, we click and drag it towards the edge and this widens the 'Red' channel. Occasionally a warning symbol will appear on the histogram (see Screenshot 1). Click this symbol as and when it appears and it will refresh the histogram and show current data. We repeat this process for the 'Green' and 'Blue' channels until we're satisfied we've extracted all we can from this stretch. After making a right click with the mouse on the layer, we can select 'Merge Down' and the histogram widens. We repeat this stretching process twice more to ensure all possible detail is extracted.

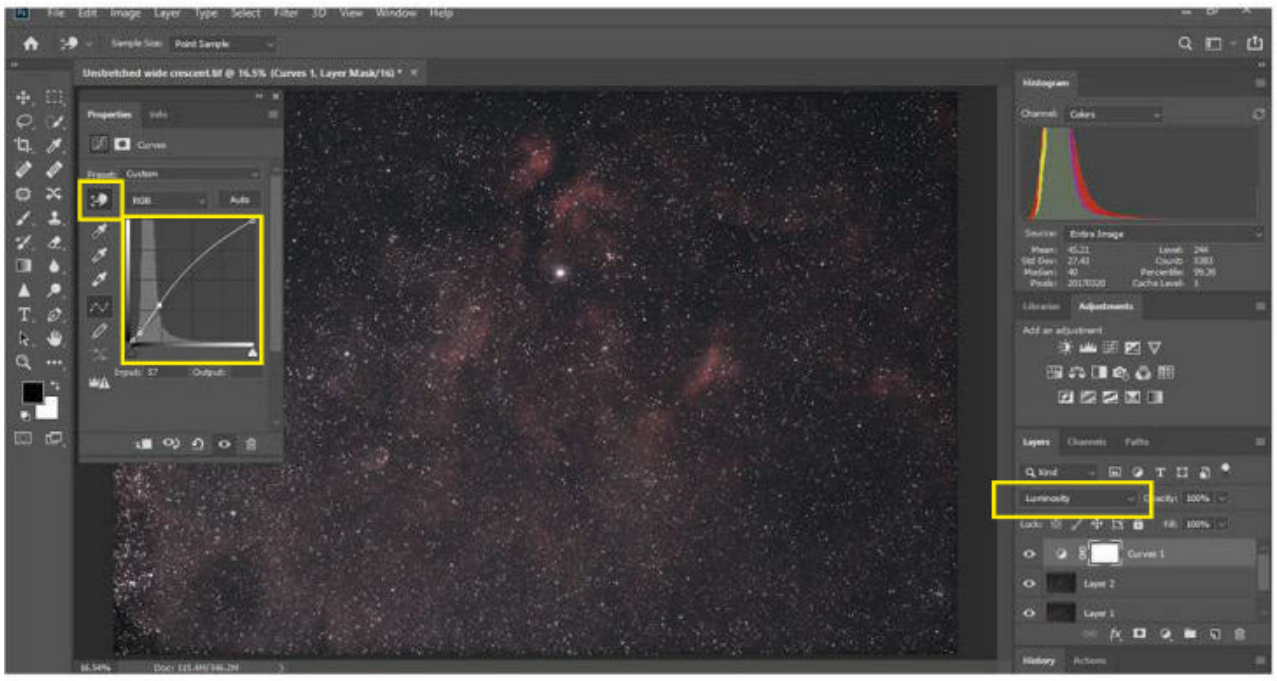


Our starting image of the Sadr Region, before Curves has been applied

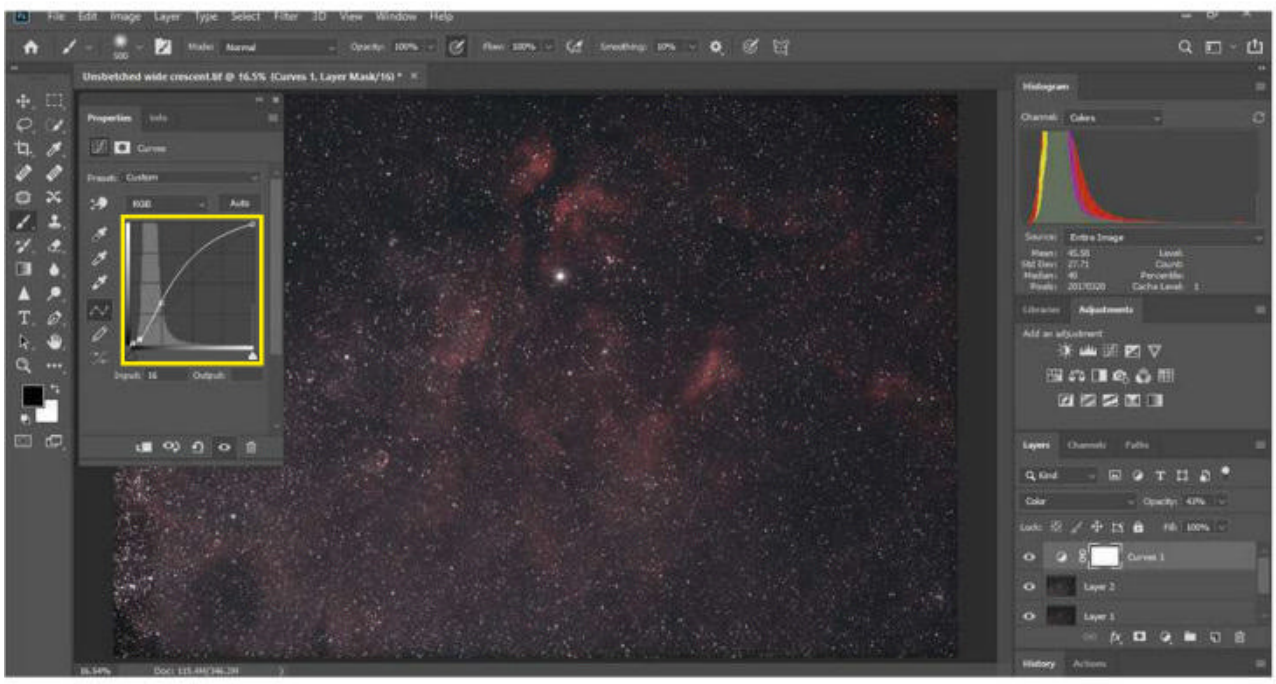


▼ Screenshot 1: creating a layer which duplicates the base layer but doesn't overwrite it

ALL PICTURES: CHARLOTTE DANIELS



▲ **Screenshot 2: creating a new layer and opening Curves, ready to increase tonal contrast**



▲ **Screenshot 3: after adding a new layer, use Curves to create an 'S' shape by bending the line**

We now create a new layer and open Curves ('Image > adjustments > Curves'). You'll see a histogram with a Curves graph appear in the function window (highlighted in Screenshot 2). The top right of the graph represents the highlights present in the image, while the lower left area relates to the shadows. By gently bending the straight, diagonal line across the graph we can increase tonal contrasts. The extent to which we can do this stretch will depend on image quality.

A brighter outlook

Click on the icon of a pointing finger (highlighted in Screenshot 2). This allows us to add 'anchor points' to the Curves histogram. By clicking on the line exactly where it meets each end of the histogram curve, we plant a point at each edge. Click on one of these to select it (Screenshot 2). By using the arrow keys, we move the right-most anchor point upwards to create a gentle curve in the line; as this curves, the image will brighten. To darken the shadows in our image, we could move the left-most anchor point downwards.

When stretching data in this way, colours can become over-saturated, making them appear harsh. It's a sign that data is being 'clipped' or lost. Limit this effect by changing the blend mode to 'Luminosity' (see Screenshot 2). This retains tone adjustments but prevents colour saturation, meaning we achieve contrasts without overblowing the colours. With the mouse we make a right click on our layer and select 'Merge Down'.

3 QUICK TIPS

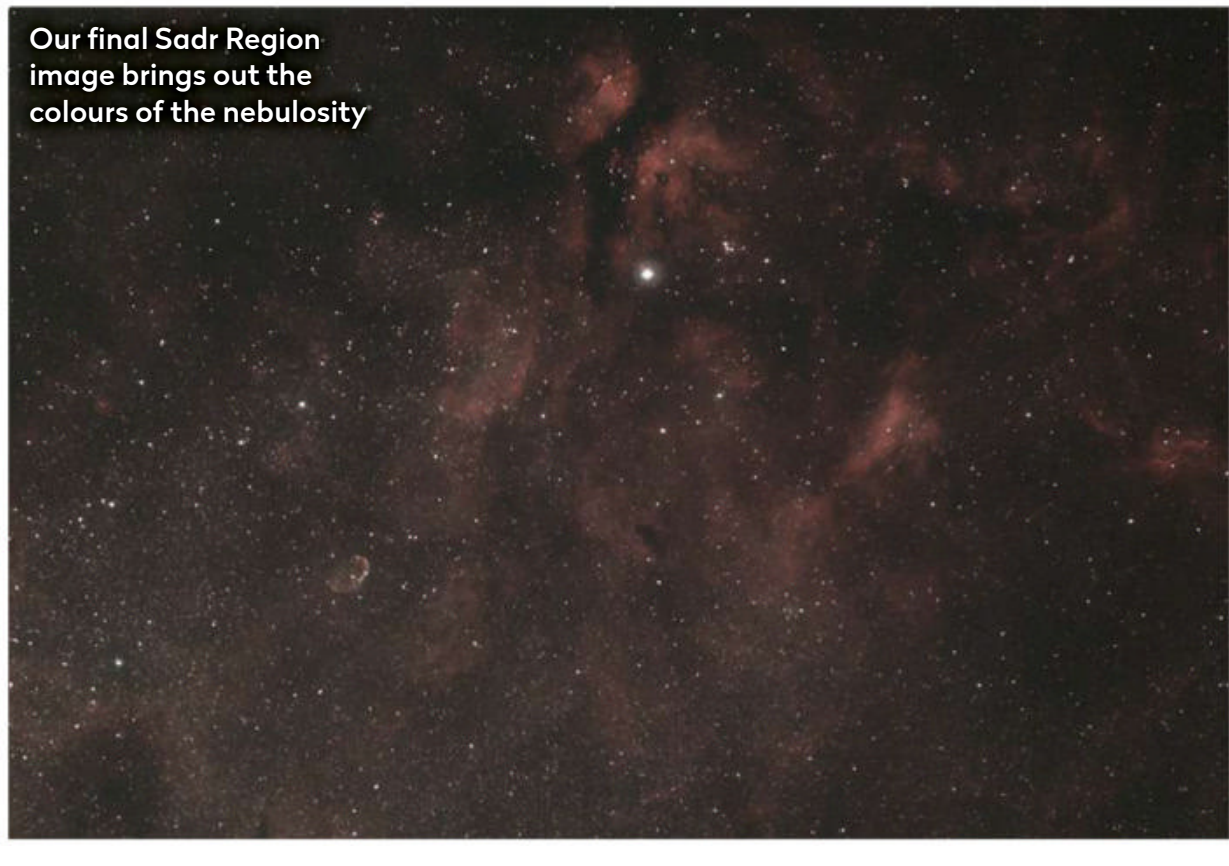
1. Use the eye symbol for each adjustment layer to see whether it improves the image.

2. Use the 'Opacity' slider to reduce the effect of an alteration, or the noise (unwanted artefacts) it creates.

3. It is better to perform several gentle stretches than a single big stretch, which adds noise early on.

After adding a new layer we use Curves again; this time attempting a gentle 'S' shape by bending the line (Screenshot 3), stopping once the image becomes noisy. This time, we merge down and change the layer's blend mode to 'Colour'. This applies the colour adjustments and not the increased brightness that made the adjustment noisy. Whether the 'Colour' or 'Luminosity' blend modes will benefit an image is trial and error; if some noise remains it is best to delete the layer and start again, or we can reduce the 'Opacity' of the latter, setting the slider to 43% . We perform a final, small Curves stretch until satisfied we have extracted all we can. Finally, due to the high number of stars, we apply 'Dust and Scratches' ('Filter > Noise > Dust and Scratches') with the 'Radius' set to 3 to remove some of the stars and reduce noise.

Charlotte Daniels is an amateur astronomer, astrophotographer and journalist



Our final Sadr Region image brings out the colours of the nebulosity

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

More **ONLINE**
A gallery containing these and more of your images

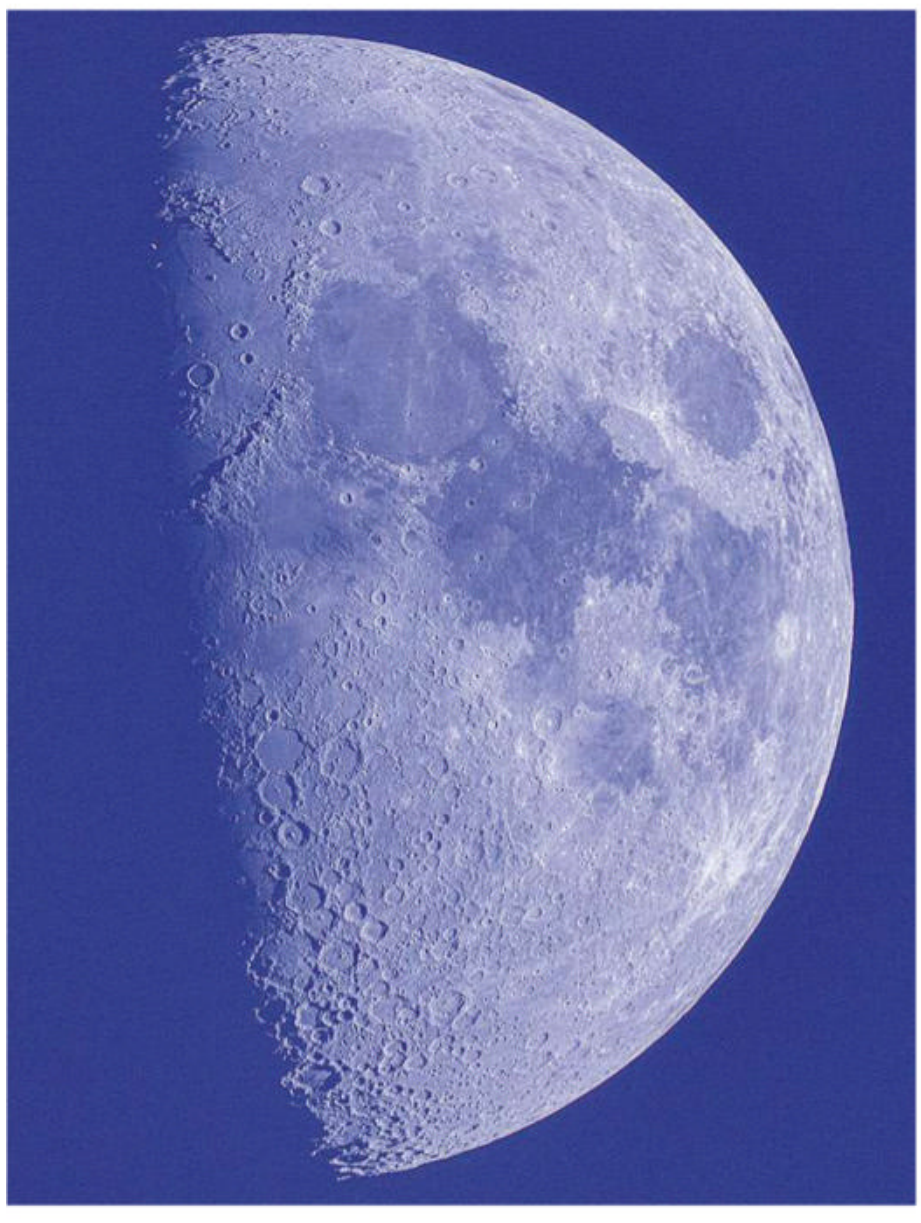
△ The Orion and Running Man Nebulae

PHOTO OF THE MONTH

David Wills, Castillejar, Spain, 14–20 January 2021

David says: "This is a composite of two images, one for the nebula's main part and one for core detail. I'm pleased as it wasn't captured in the best conditions. I spent time gathering data with the luminance filter, but it didn't add anything so I ended up using Ha data (hydrogen alpha) as the luminance layer." **Equipment:** Starlight Xpress Trius SX 694 Pro mono camera, Takahashi FSQ-85ED f/5.3 quad apo refractor, iOptron CEM60 mount **Exposure:** Main: Ha 62x 600", R 56x 180", G 41x 180", B 50x 180"; core: R 85x 30", G 216x 30", B 231x 30". Total: 22 hours 7 minutes **Software:** PixInsight, Photoshop

David's top tips: "Spend more time gathering Ha data for this target and use it as a luminance layer. To enhance dust clouds around M42, I used 'Local Histogram Equalization' in PixInsight to preview changes before applying them to the whole image. For detail in the core I used 30" exposures. I processed the main image and central core separately in PixInsight, then layered them together in Photoshop. After I was happy with the layered images, I increased the saturation of the core image to match the nebula's outer colours, which enhanced the final image."



△ Daytime Moon

Ollie Bacon, Sapcote, Leicestershire, 21 January 2021

Ollie says: "I watched Moonrise times and the weather for weeks to figure out the best time; I took 30 shots and the final image is made up from the four best."

Equipment: Canon 1100D DSLR, Sky-Watcher Skymax 127 Maksutov-Cassegrain, Sky-Watcher Supa-Trak mount **Exposure:** ISO 100, 1/60" **Software:** RegiStax, Photoshop

△ Gazing at the Milky Way

Mauro Cirigliano, Teide National Park, Tenerife, 13 May 2018

Mauro says: "I waited for the right moment for the galaxy to approach a nice boulder with the appearance of an enchanted human face observing that wonder in the sky."

Equipment: Nikon D750 DSLR, Nikon 50mm 1.8G lens, iOptron SkyGuider Pro mount **Exposure:** Sky: ISO 6400 f/4, 180"; ground: ISO 6400 f/4, 120" **Software:** Lightroom, Photoshop

△ NGC 613

Mike Selby and Warren Keller, remotely via Obstech, El Sauce, Chile, 19–22 September 2020

Mike says: "We get the worst seeing in Chile around September, so we took as much data as was practical and were rather aggressive in selecting what we used for the final image."

Equipment: FLI ProLine PL16803 mono CCD camera, Officina Stellare RiDK 500 and 700 astrographs, Officina Stellare Polar Fork and PlaneWave L-600 mounts **Exposure:** L 14.75', RGB 5.5h **Software:** MaxIm, PixInsight, Photoshop

△ Bok globules in the Rosette Nebula

Emil Andronic, Bushey, Hertfordshire, 21–24 January 2021

Emil says: "These 'animal parade' Bok globules were the first light for my new ASI 294MM camera and 3nm Chroma filters."

Equipment: ZWO ASI 294MM Pro mono camera, Astro-Tech 106LE triplet refractor, Sky-Watcher EQ6 Pro mount **Exposure:** Ha 39x 300", 1x 600", OIII 10x 300", SII 10x 300". **Software:** SGPro, Astro Pixel Processor, PixInsight, Photoshop

Mineral Moon ▷

Robin Durrant, Brighton, 24 January 2021

Robin says: "It's nice to see the Moon – my favourite subject for imaging – in all its colour. This is a mosaic of 25 frames."

Equipment: ZWO ASI 178MC colour camera, William Optics ZenithStar 71 apo refractor, iOptron AZ Pro mount **Exposure:** 25x 500-frame video at 10 f/s **Software:** SharpCap, AutoStakkert!, MICE, Photoshop

◁ Geminid meteor shower

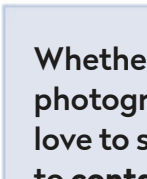
Parisa Bajelan, Alamut Valley, Alborz, Iran, 14 December 2020

Parisa says: "This is a composite of 27x 20-second frames taken over two hours at the peak of the Geminids."

Equipment: Canon 6D DSLR (modified), Canon 16–35mm lens, Manfrotto MT190CXPRO4 tripod **Exposure:** ISO 5000 f/2.8, 20" **Software:** Lightroom, Photoshop

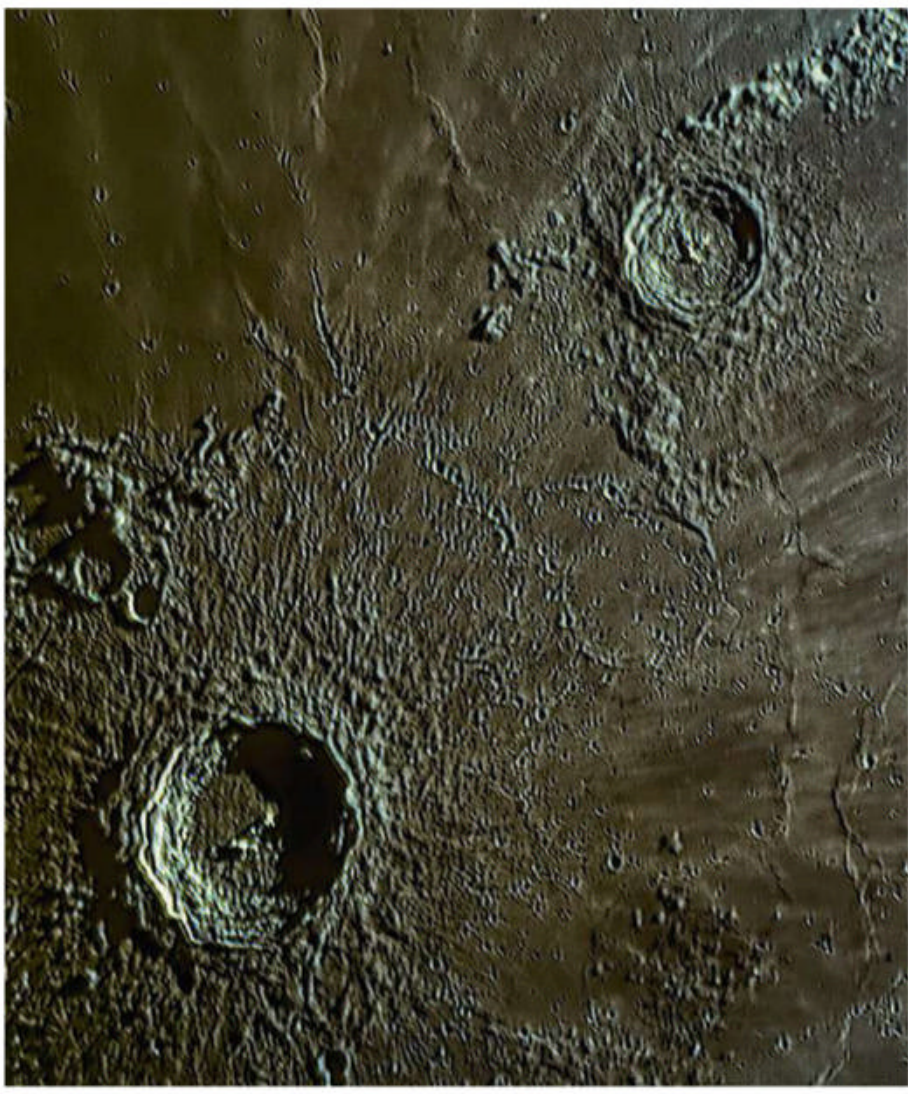
▽ The Grus Quartet

Fernando Oliveira de Menezes, Munhoz, Brazil, 27 July 2019



Fernando says: "Galaxy NGC 7552 is at the top, the smallest is NGC 7590, with NGC 7599 next to it. In the middle is NGC 7582, a type 2 Seyfert with a black hole millions of times the mass of our Sun."

Equipment: QHY16200A mono CCD camera, Sky-Watcher Esprit 150ED apo triplet, iOptron CEM60-EC mount **Exposure:** L 15x 500", RGB 43x 300" **Software:** APT, PixInsight, Photoshop



△ Copernicus and Eratosthenes

Michael K Jamieson, Snitterby, Lincolnshire, 31 May 2020

Michael says: "It's not easy at high magnification to keep on target, but using good capture software allowed me to keep pausing and repositioning." **Equipment:** ZWO ASI 224MC colour camera, Meade LX90 SCT **Exposure:** 10,000 frames, best 2,500 stacked **Software:** SharpCap Pro, AutoStakkert!, RegiStax, PhotoShop

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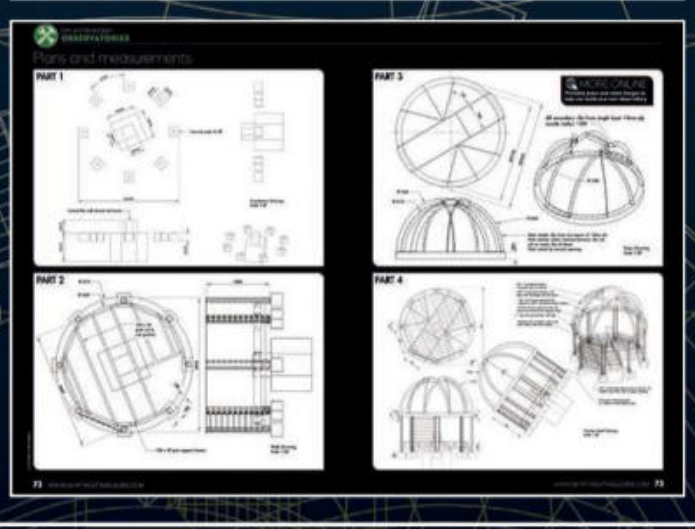

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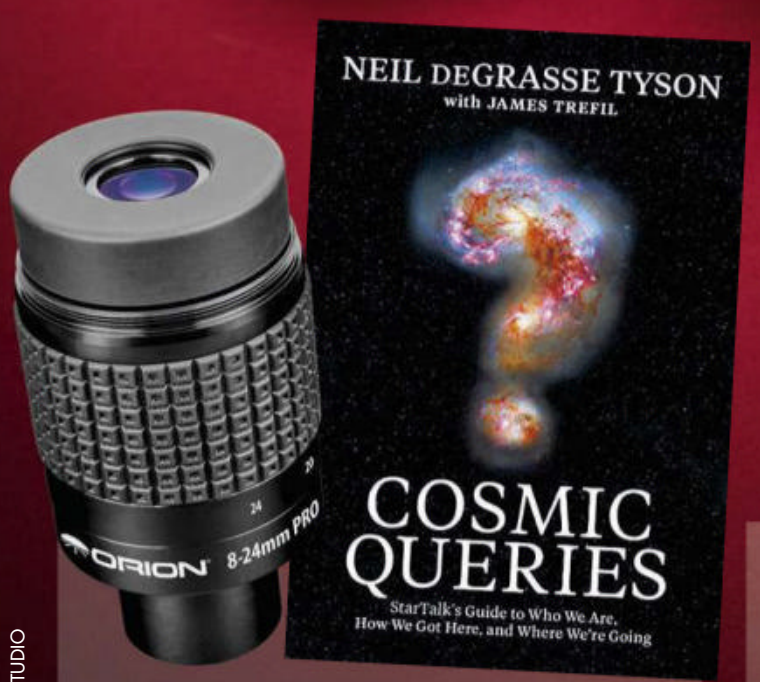


PLUS: Books on the great cosmological questions and zoology in space, plus a roundup of must-have astronomy gear

HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★★ Very good
★★★★★ Good ★★★★★ Average ★★★★★ Poor/avoid

@THESHED/PHOTOSTUDIO

FIRST LIGHT

Altair 72mm
EDF Deluxe refractor

A versatile, lightweight telescope with super-smooth movement

WORDS: CHRIS GRIMMER

VITAL STATS

- **Price** £499 (Deluxe), £459 (Standard)
- **Optics** Doublet refractor with FPL53 (synthetic Fluorite) lens
- **Aperture** 72mm (2.8-inch)
- **Focal length** 432mm, f/6
- **Focuser** CNC-machined, dual-speed rack and pinion
- **Extras** Tube rings, dovetail bar, rear camera angle adjuster, finderscope bracket, 20mm extension tube
- **Weight** 2.5kg
- **Supplier** Altair Astro
- **Tel** 0126 373 1505
- **www.** altairastro.com

Small, short focal length refractors are extremely popular and – with a weight of 2.5kg and length of 32.5cm – the Altair 72mm EDF is marketed as a travel scope. It's no one-trick pony, however, as the 72mm EDF is sold in two different configurations. Here we review the 'Deluxe' version, which is supplied with a CNC-machined dual-speed focuser, rear camera rotator and extra height tube rings. The 'Standard' version, meanwhile, is tailored for visual use and is fitted with a white powder-coated aluminium focuser that doesn't include the rear camera rotator.

The telescope arrived in a single box, with its tube rings and a dovetail bar already in place. We noted that a carry case is not supplied. Our first impressions of the Altair 72mm EDF Deluxe is that it feels well made; it has a reassuring weight when it's held in the hand and everything feels solid and put together with care. Both versions come with a 15cm dovetail bar; despite our attempt to mount the 72mm EDF Deluxe as far forward as possible in the saddle, with the dovetail bar installed well under the focuser, we were unable to balance the declination axis with either a DSLR or CCD camera. Balancing the scope with a diagonal and eyepiece, however, was not an issue, although it's worth noting that heavier eyepieces may prove more difficult.

The aluminium dew shield has a firm and smooth movement and it stayed in place without any issue, despite not having a thumb screw to secure it. With the addition of a dew heater strap, we had no issue with dew, despite being out during some very damp and misty winter evenings. Altair sells a matching field flattener that has been designed specifically for this telescope and its astro cameras; this screws onto the focuser and has a matching thread that allows Altair cameras to screw directly to the flattener with the ideal spacing (55mm). It is worth noting that this thread is not the standard T-thread/T-mount, which resulted in us not being able to obtain ideal spacing due to the necessity of adding thread adaptors; the closest we could achieve was 57mm with our CCD camera, and 65mm with a DSLR.

Ready to test

At 2.5kg, the Altair 72mm EDF Deluxe is lightweight and short enough for robust star trackers, but for the purpose of this review we tested it on a lightweight equatorial mount. With a DSLR attached and with a small adjustment to the tension adjuster, the focuser extended smoothly and felt very secure. The ▸

A superior, smooth focuser

The CNC-machined focuser that's fitted to the 'Deluxe' Altair 72mm EDF is designed with astrophotographers in mind. It's a solid rack and pinion focuser, with smooth movement provided by both coarse and fine focus knobs, while a tension-adjuster allows even the heaviest of cameras to be attached. This model has dual rotators that make image alignment easy, while maintaining precise focus without a worry of slippage. The addition of a finder shoe between the two rotators allows for a finderscope/guidescope to be installed, allowing it to be rotated independently of the telescope, camera and eyepiece. The barrel of the focuser is threaded, meaning Altair's field flattener can screw directly onto the scope.

Once your camera is screwed onto the field flattener, there are no friction connections in the imaging setup, eliminating the risk of the camera slipping. With pre-drilled mounting holes, the focuser is designed to allow a motor drive to be installed, which is a nice touch.

Fluorite doublet

The lens in the Altair 72mm EDF is an air-spaced doublet, with one of the lenses being made of S-FLP53 ED glass, known as synthetic fluorite. This helps with colour correction and limits colour halos around stars. Altair has also added oversized glass, meaning there were no signs of vignetting when it was used with a modified DSLR.

Extra height tube rings

The Deluxe version is supplied with a pair of machined tube rings that are especially designed for this scope. The rings have a spacer installed that allows greater clearance between the scope and the mount saddle. The additional height ensures that the tension-adjuster knob is still accessible and isn't hindered by the dovetail bar.

Dovetail bar

The Deluxe version comes with a longer dovetail bar to help you achieve balance in the declination (dec.) axis, an issue all refractor users are familiar with. While this was an improvement over the 'Standard' model, we found that even with a light camera attached balance was still unachievable.

Aluminium tube

The Altair 72mm EDF has a full aluminium optical tube, which helps to keep the weight down to just 2.5kg and also allows for rapid cooling (thermal equilibrium). This easy heat transfer also helps with dew prevention, allowing the heat from a dew strap to reach the main optical element.

KIT TO ADD

1. Altair 1.0x field flattener

2. Altair magnetic filter holder

3. Altair QuadBand 2-inch light-pollution filter

▸ dual-speed dial made fine, precise focus easy; the focus wheels offer a good level of resistance, with zero play. The focuser has a distance scale that is clear to see, making it easy to repeat rough focus. Over the course of five hours, we found that the focus held perfectly, despite a significant drop in temperature.

Visual results

We put the Altair 72mm EDF Deluxe through its paces over several nights of visual astronomy and astrophotography. Pointing the scope at a 90%-illuminated Moon resulted in a crisp image with no hint of colour fringing, with stars appearing sharp to the edge of the field of view with no distortion. This was also the case in the DSLR images, which showed no vignetting and did not require flat frames to be applied. There was evidence of some curvature when using the Altair field flattener, but this may have been due to the incorrect spacing. This was not evident, however, when using a third-party flattener on the scope.

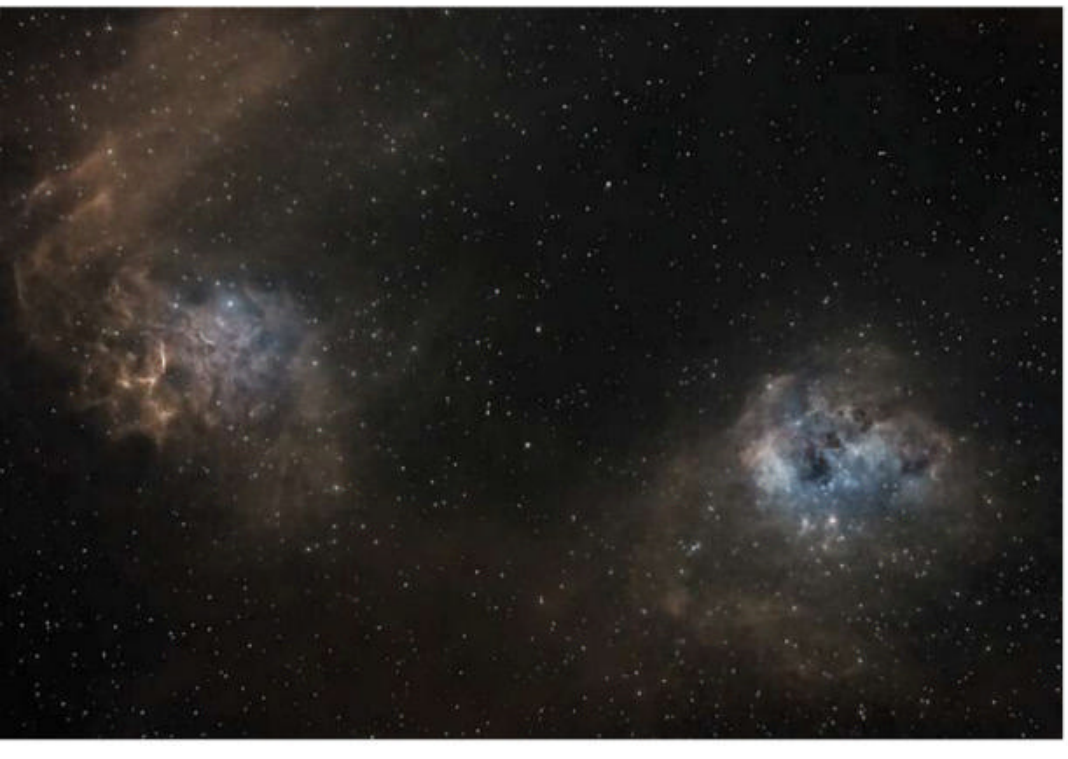
A focal length of 432mm gives the Altair 72mm EDF Deluxe a wide field of view, and when it's paired with a DSLR or a medium-sized astrocam it will allow you to capture the larger nebulae or even large targets such as the Pleiades open cluster. Overall, we were very impressed with the Altair 72mm EDF Deluxe; not only will this fit comfortably in a backpack for those trips to dark-sky sites, but it would also be an excellent addition as a home-imaging or visual scope in a permanent observatory. Altair has really thought about the end user in developing the 'Deluxe' version of its 72EDF, resulting in some well-designed additional features.

VERDICT

Build & design	★★★★½
Ease of use	★★★★½
Features	★★★★½
Imaging quality	★★★★½
Optics	★★★★½
OVERALL	★★★★½

Threaded camera connector

The focuser barrel is threaded allowing Altair's matching field flattener, or suitable adaptor, to screw directly onto the telescope. This allowed us to connect our camera directly to the focuser, giving a solid connection and eliminating any risk of your camera coming loose and falling.



▲ **The Flaming Star Nebula, taken with the 72mm EDF Deluxe and a modified Canon 70D – using an Altair QuadBand filter, Hotech field flattener and 50mm guidescope – with 94x 120" exposures**

▲ **The Monkey Head Nebula, taken with the 72mm EDF Deluxe and a Starlight Xpress H694 mono camera, using an Astrodon 5nm Ha filter and a field flattener – with 13x 900" exposures**

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Vixen Atera H12x30 stabilised binoculars

Portable, image-stabilised binoculars, which are ideal for general astronomical use

WORDS: STEVE TONKIN

VITAL STATS

- **Price** £593
- **Optics** Fully multi-coated
- **Aperture** 30mm
- **Magnification** 12x
- **Prisms** Roof (internal) and right-angled (eyepiece turrets)
- **Angular field of view** 4.2°
- **Focusing** Centre focus, moving internal lens group
- **Eye relief** 17.5mm
- **Interpupillary distance** 55–75mm
- **Weight** 422g (without batteries)
- **Supplier** Bresser
- **Tel** 01342 837098
- **www.** bresseruk.com/en/home/

As image-stabilised binoculars occupy a unique niche in binocular astronomy, it always piques our interest when a new player enters the field. The Vixen Atera H12x30 binoculars have a one-piece body with adjustable eyepiece turrets. As well as a hard-shell case, there's a 25mm-wide neoprene neck strap, individual eyepiece caps, but no caps for the objective lenses. Although it's not armoured, the fibreglass-reinforced polycarbonate body is smooth to the touch.

The eyepiece turrets incorporate BaK4 subsidiary prisms; you can change the interpupillary distance (IPD) – the distance between the pupils of your eyes – by rotating these turrets, which have enough resistance to movement to prevent you from accidentally altering the IPD. There is the usual dioptre adjustment (for adjusting for any difference between your eyes) on the right eyepiece, which is also stiff enough to prevent any accidental adjustments. The centre-focus wheel is situated at the objective lens end of the body and it's light enough to be operated with your little finger while having a satisfyingly smooth feel with no perceptible backlash. Vixen refers to its image stabilisation system as 'vibration cancelling' and the 'Vibration Canceller' switch is located on top of the body, conveniently placed for operation with your left forefinger. The battery compartment is out of the way on the front underside of the body, with enough room behind it to comfortably accommodate your thumb. Sensibly, its cap is tethered, which will help to prevent you losing it if you need to change batteries in the dark.

Getting comfortable

The eye relief (the ideal distance your eye should be from the eyepiece) is specified as 17.5mm and we were able to see the entire field of view with the four-position eyepiece cups in their most extended position; you can experiment to see which position is most satisfying. The lowest position is 2mm above the ▸

Keeping steady

The 'Vibration Canceller' is Vixen's name for its image-stabilisation system. In each light path, there is a gimbal-mounted prism system that is controlled by gyroscopic sensors and small motors. It compensates for high-frequency vibration with a magnitude of up to about 3°, ie the shakiness that reduces your ability to resolve fine detail. The system is good enough, and the binoculars are light enough, to enable you to hold them with one hand, freeing the other for notes.

The system is activated with a lever on a rotary toggle switch (which is a little small for gloved fingers). A green LED indicator, which is visible when you take the binoculars away from your eyes, alerts you if you have left it switched on but, to preserve battery life, it also times out after five minutes of no motion. The 'Vibration Canceller' works well with slow panning across the sky, but large fast movements can induce some 'overshoot', which is disconcerting, but it damps down within less than a second.

ALL PICTURES: @THESHED/PHOTOSTUDIO

Effective coatings

The anti-reflective multi-coatings on the transmissive surfaces of lenses and prisms ensure that a maximum amount of light is passed to your eyes. The roof prisms have phase coatings on their apexes and high reflectivity dielectric coatings on their reflective surfaces to give good contrast in the eyepiece.

Readily available batteries

The Atera binoculars take two common AAA (aka LR03) batteries, so carry a few spares to ensure that you can always use the 'Vibration Canceller' system. The specified battery life is up to 12 hours at 20°C with alkaline batteries, but expect this to be considerably shorter in cold weather.

Good IPD range

The generous interpupillary distance (IPD) range (the distance between the pupils of your eyes) of 55mm to 75mm, combined with small diameter (42mm) eye cups, means these binoculars will suit a wide variety of faces. Even at the minimum IPD, there is 12.5mm between the eyepieces, which easily accommodates most nose sizes.

Internal focusing

The sliding eyepiece tubes found on conventional centre-focus binoculars are a potential route in for unwanted water. Here, the problem is eliminated by having internal focusing so, although the specifications state that the binoculars are not waterproof, you can still use them on dewy nights, provided you dry the body afterwards.

FIRST LIGHT

Hard-shell case

These are potential 'go anywhere' binoculars, so a decent case is essential. The dual-zipped hard-shell case has a thin foam padding on the inner surfaces to protect the binoculars. You can use either a removable shoulder strap or a belt loop for convenience when you are carrying it.

KIT TO ADD

1. Bresser BR-LP15 cleaning kit

2. Bresser binoculars/ camera neck strap (an upgrade from the supplied standard one)

3. *Turn Left at Orion* by Brother Guy Consolmagno

▸ surface of the eye lenses, which reduces the effective eye relief to 15.5mm, but this was easily enough to enable us to see the entire 4.2° field of view when we wore spectacles. If you have long-sightedness, or mild to moderate short-sightedness, there is a sufficient focal range to accommodate your eyes if you prefer to observe without glasses, and we found that the 2.5mm exit pupil reduces the effects of mild astigmatism to tolerable levels.

By eliminating any vibration blur, the 'Vibration Canceller' system makes it easy to focus the binoculars. Focus is sharp across the central three quarters of the field of view, with slight softening at the periphery – due to coma and astigmatism – visible on bright stars. There is a tiny amount of pincushion distortion, where straight lines appear to curve outwards from the centre, which is necessary to negate any rolling-ball effect when you are panning.

Control of stray light

Stray light is well controlled, so you won't get ghost images if you are examining the Moon, which is one of Vixen's suggested targets for the binoculars. When it comes to chromatic aberration – an effect seen as unwanted coloured rings around brighter objects – it's not perceptible in the middle of the field of view, and it only slightly affects high-contrast objects like the lunar terminator when they are off-axis. We noted that the combination of excellent control of stray light and the use of effective coatings throughout preserves colour fidelity and contrast. The apparent field of view is only 50.2°, which is on the narrow side for astronomical binoculars, but it does mean that you don't get severe edge-of-field aberrations.

You need to remember that these are only 30mm aperture binoculars with a 2.5mm exit pupil, and consequently the night-time images are not particularly bright. The 'Vibration Canceller' system gives you about an extra quarter of a magnitude of depth, but it doesn't make the brightest stars perceptibly brighter. This was apparent when we tested the system on the Pleiades, M45, where its only effect was to bring a dozen or so more stars into view. It's good, however, on some brighter double stars; we discovered that we could not split Iota (ι) Cancri, which has a separation of 30 arcseconds, until we activated the 'Vibration Canceller'.

If you want a highly portable pair of image-stabilised binoculars for general and occasional astronomical use, the Vixen Atera H12x30 is well worth considering, but you would probably want a bit more aperture (and, therefore, image brightness) in binoculars that are primarily for astronomy.

VERDICT

Build & design	★★★★★
Ease of use	★★★★½
Features	★★★★★
Image stabilisation	★★★★½
Optics	★★★★½
OVERALL	★★★★½

ALL PICTURES: @THESHED/PHOTOSTUDIO

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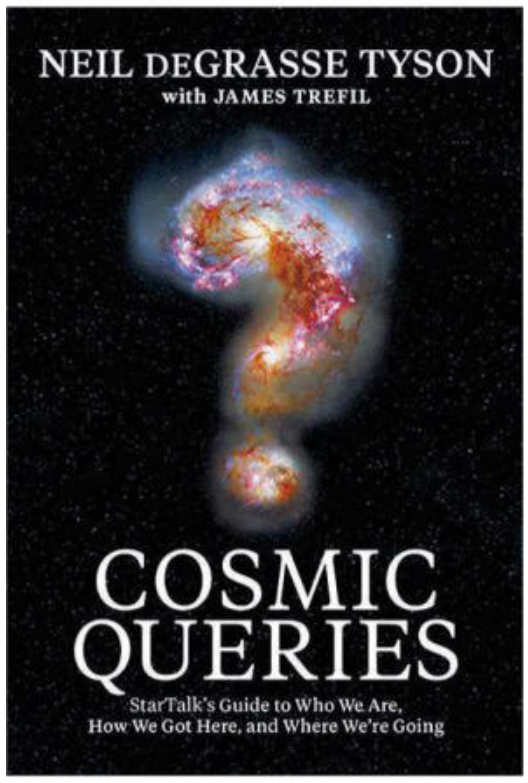


Cosmic Queries: StarTalk's Guide to Who We Are, How We Got Here, and Where We're Going

Neil deGrasse Tyson
National Geographic
£20 ● HB

Cosmic Queries is a book that covers just about everything. How do we know what we know? How did the Universe get to be this way? Are we alone? These are just some of the questions explored over 10 chapters, each focusing on a different big question, in this aptly-named tome.

StarTalk is Neil deGrasse Tyson's popular podcast where science meets pop culture, which became a late-night talk show on US TV. Cosmic Queries (not the book) is a segment of the podcast where listeners' questions about the Universe are answered and this latest title includes the best of these. The book really does remind you of a podcast or TV programme. The language is very easy, if a little flowery in places, and the illustrations are absolutely gorgeous. It's ideal for beginners or those who have a love for looking up into the night sky but don't want to get into the nitty gritty details.

One chapter that I did really enjoy looked at how we define life. The chapter starts with the 1952 experiment that attempted to generate the molecules necessary for life, before discussing whether rocks from space could have seeded life on Earth. The discussion then turns to DNA, natural selection and complex life, before a section devoted to synthetic life and our quest to build artificial intelligence. This nicely sets the scene for how we might define any life that is different to what we know.

There are a few drawbacks to the book though. *Cosmic Queries* does try to cover a lot of ground, so much so that in places where I would have liked to have seen more detail, the book just skips on to another topic. Nor is it a particularly novel concept – there are many examples of books that are an extension of a TV series. I am also not a fan of the random tweets that have been inserted throughout the pages, which are vaguely related to the topic in question.

▲ **Did life on our own planet come from space rocks? This question and others are pondered here**

That said, if you're a fan of Neil deGrasse Tyson's StarTalk podcast, you're bound to find much in this book to enjoy. ★★★★☆

***Laura Nuttall** is a senior lecturer in gravitational waves at the University of Portsmouth*

COKADA/ISTOCK/GETTY IMAGES

Interview with the author
Neil deGrasse Tyson

What is our greatest cosmological achievement?

In a vibrant civilization, one that values exploration and discovery, achievements are ongoing, and often exponential in pace. For this reason, I don't rank achievements, I merely observe them. That being said, I think the greatest achievement in all of civilization is the awareness that the Universe is knowable: that its deepest mysteries are tractable with science.

Do we know how the Universe began?

The Big Bang is a tight description of the early Universe, bolstered by successful predictions it makes about the Universe we inhabit 14 billion years later. But it opens doors to the next round of questions, not previously visible to us. What was around before the Universe? Are there other universes? Will the Universe end? If so, how? Thirty years ago, we didn't have the luxury of asking those questions because they were not visible to us from the point at which we were standing. What we call dark matter and dark energy in the Universe, on the largest scales, account for 95 per cent of what's out there, yet we have no idea what they are. We know less than 5 per cent of what's driving the Universe, but that 5 per cent contains all our known laws of physics, chemistry, and biology.

What are the questions you would most like answered?

Are we smart enough to figure out the questions we've posed to ourselves? And, more importantly, are we smart enough to even know what questions to ask?

***Neil deGrasse Tyson** is an astrophysicist at the American Museum of Natural History, New York City*

Helgoland

PACKED WITH IDEAS

Carlo Rovelli
Allen Lane
£20 ● HB

For publishers, quantum physics is the gift that keeps giving. Although it's one of the most successful scientific theories ever, physicists can't agree on its implications for our understanding of reality. For almost a century the debate has waxed and waned, with many books discussing the pros and cons of different interpretations.

This latest contribution to that debate by Italian physicist Carlo Rovelli takes as its starting point Heisenberg's 1925 trip to the titular island to recover from hayfever. Whilst there he came up with a startling insight: we shouldn't worry where an atom or electron is when it's not being observed. Heisenberg's maths worked (and still works) perfectly. But it begs the question: what are we doing when we 'observe' something, and why does this act matter so much?

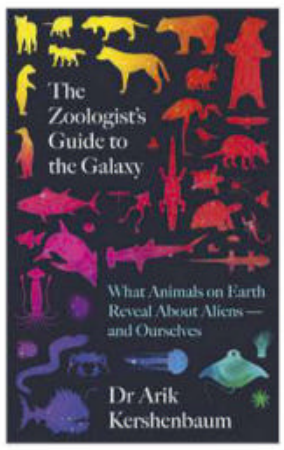
In his beautifully written book, Rovelli explains the importance of Heisenberg's work and all the competing interpretations that have aimed to get around this observation problem. Much of the book concentrates on Rovelli's own idea of 'relational' quantum physics, in which it is not the objects under observation that matter but the interactions between them, and draws on supporting evidence in the physicist-philosopher Ernst Mach's work, as well as early Buddhist writings.

The book's brevity is both an advantage and a drawback, but the notes provide more technical information and links to more detailed discussions elsewhere. Overall, a fine introduction to a notoriously difficult topic. ★★★★★

***Pippa Goldschmidt** is an astronomy and science writer*

The Zoologist's Guide to the Galaxy

Arik Kershenbaum
Viking
£18.99 ● HB



The laws of physics and chemistry apply throughout the Universe, while those of biology apply only on a single planet, right? No, wrong. At least that's what this book says, and the case it makes is persuasive.

The basis is that natural selection applies to life everywhere. Hence, on exoplanets with Earth-like environments, similar life forms will evolve. Such natural selection could apply to pretty much everything, from the chemical and cellular basis of life through to the behaviour of large life forms. Kershenbaum focuses on the latter, so you won't find anything about carbon chauvinism, or the special qualities of water. No worries: his subject is huge enough, and he deals with it brilliantly.

I loved his introduction of 'the speed of smell' when considering possible forms of communication. His discussion of intelligence is excellent, as is his consideration of whether there might be a common feature to intelligent life forms everywhere.

Do I have any quibbles? No one can write a book of 300-plus pages without there being a few things that some don't agree with, and even a few things that aren't quite right. He says that "for the first 3,200 million years, no one ate anything other than sunlight." This comment about life on Earth is only true for a very narrow definition of 'eating', because microbes have been eating things for eons. But every author is entitled to a few slips of the pen. Would I rob this author of a star for such a slip? Perish the thought. It's a terrific book. ★★★★★

***Wallace Arthur** is the author of The Biological Universe: Life in the Milky Way and Beyond*

30-Second Space Travel

Charles Liu, Karen Masters, Allen Liu
Quarto
£14.99 ● HB

Is it possible to explain 50 key ideas on space travel, each in 30 seconds? *30-Second Space Travel*, which is part of a wider '30-second' collection, aims to do just that. It provides readers with an introduction to the topic, covering aspects including the historic Space Race, the basic physics of space flight and concepts of future space habitats. Each idea explored in the book is framed with a 30-second digest, a 3-second glance and a 3-minute thought-provoker.

For readers who are interested in learning more about human space exploration, this is a very accessible springboard from which you can dive off. What can often be quite complex aspects of space exploration, such as orbital mechanics and rocket launches, are explained simply, belying the expertise that the three authors possess (they are all astrophysicists). However, those who are already familiar with the subject may find that it does little to quench their thirst for greater detail.

Collage illustrations offer striking visual cues to each concept, and many readers will appreciate the use of art to communicate and engage people in the science of space. A downside to the book is that it perhaps tries to cram too much around one idea. Additional motes of information – cross-referenced sections, block quotes, and one-line biographies – only served to distract this reader and make the pages feel cluttered. However, if you know anyone who has a casual interest in space, then this book would make a lovely coffee table gift to encourage their curiosity. ★★★☆☆

***Nisha Beerjeraz-Hoyle** is a space science and astronomy writer*

Ezzy Pearson rounds up the latest astronomical accessories

GEAR

1 Explore Scientific two-room observatory tent

Price £233 • **Supplier** Telescope House
Tel 01342 837098 • **www.telescopehouse.com**

This pop-up tent is a great observatory solution – whether you're looking for something to take with you into the field or a cheap home option. Set your equipment up in one of the two roofless rooms to observe at night and put a cover on for day protection.

2 Astronomik OIII MaxFR narrowband filters

Price £150 • **Supplier** Widescreen Centre
Tel 01353 776199 • **www.widescreen-centre.co.uk**

Ideal for fast focal ratio scopes, this narrowband filter series creates clean frames for your astro imaging by cutting out all light apart from that produced by key molecules. Available in hydrogen-alpha, OIII and SII.

3 Fjallraven Byron hat

Price £35 • **Supplier** Cotswold Outdoor
Tel 01666 336447 • **www.costwoldoutdoor.com**

Keep your head warm throughout the night with this beanie hat. The hat is double knitted from 100 per cent wool to hold in the heat and is turned up at the bottom to ensure a snug yet comfortable fit.

4 ZWO filter draw system for Canon EOS lenses

Price £97 • **Supplier** 365 Astronomy
Tel 07912 784737 • **www.365astronomy.com**

This system allows you to change between filters while astro imaging with your Canon lenses. Preload your filters into special drawers that can then be conveniently swapped in and out without unscrewing the camera. Comes with an M42 connection.

5 Orion Pro Lanthanum zoom eyepiece

Price £174.99 • **Supplier** Orion Telescopes
Tel 0800 041 8146 • **https://uk.telescope.com**

This design stays focused even as you zoom in and out. The focal length range extends from 8mm to 24mm and can be applied to most objects.

6 Stariami origami letter writing set

Price £3.50 • **Supplier** Newton and the apple
https://newtonandtheapple.com

Write letters and make origami masterpieces; the back of these notes are decorated with constellations on a blue background, while the front is light enough to write on. Contains ten sheets and five envelopes.

Shaoni Bhattacharya interviews Dr Paul Scholz

Q&A WITH A FAST RADIO BURST ASTRONOMER

The first ultrabright radio flash to be detected in the Milky Way hints at exotic origins, coming from the most magnetic type of stars

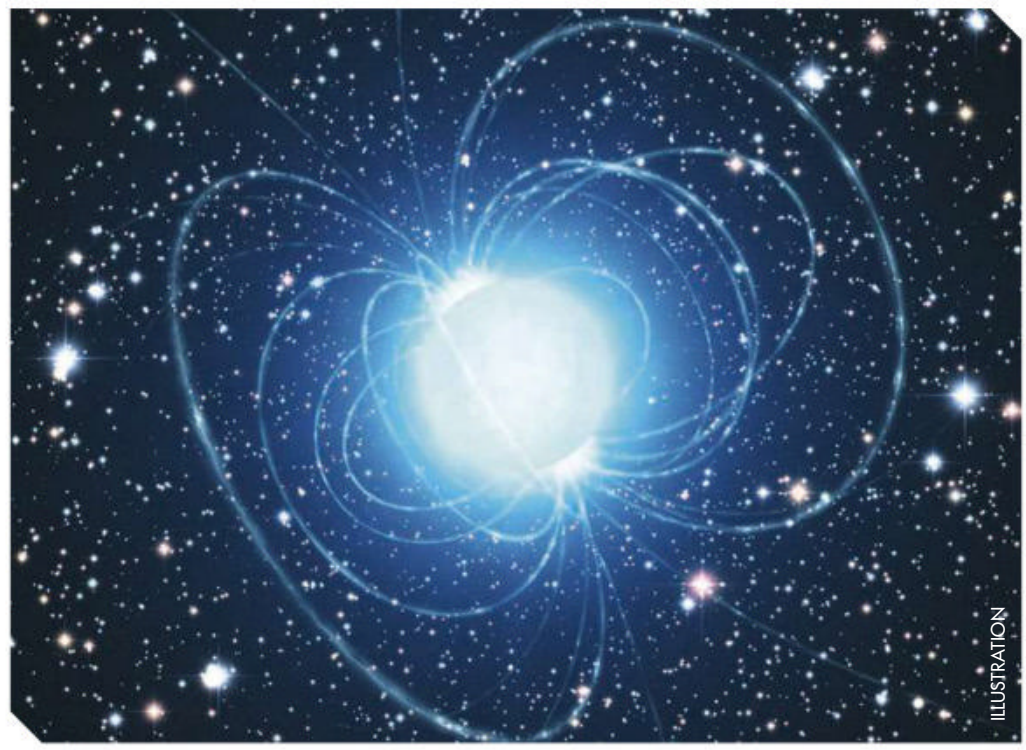
What are fast radio bursts (FRBs) and why are they of interest?
The name itself is a fairly good description of the phenomenon: it's 'fast', a millisecond to a fraction long, it's detected at 'radio' wavelengths of light, and it's a 'burst' – meaning it lasts a short time and then it turns off. Some fast radio bursts (FRBs) are seen once, but we are detecting more and more that repeat.

They are exciting because they are a mystery, and because they are so short in duration and yet so bright, which means they come from a very extreme environment – we think it's likely to be around a magnetised neutron star or magnetar. These are some of the most extreme environments in the Universe, so they are scientifically interesting.

What was the main finding of your study in the journal *Nature*?
We detected a bright radio burst from a magnetar called SGR 1935+2154 within our Galaxy. That contrasts with the previous FRBs detected, as it's in our backyard rather than far, far away. Because it's happening within our Galaxy we could see the source and see that it was a magnetar – which is a first for an FRB; where we know the source and have an object that we are able to study in more detail.

Was it suspected before that FRBs come from magnetars?
The leading theory for FRBs before this discovery was magnetars are a possible source, but one of the complications was the dozens of magnetars in our own Galaxy that we know about; as we had never seen anything like an FRB from those. So many of these theories have some sort of exotic conditions [attached], in that the magnetars are much younger than those seen in our Galaxy, or that they exist in different environments. Our discovery of an FRB coming from our Galaxy tells us that the more standard magnetars that we are familiar with are capable of producing that emission as well.

ESO/L. CALÇADA



ILLUSTRATION

▲ Bright idea: scientists are getting closer to tracing the source of fast radio burst (FRBs) to magnetars – extremely bright magnetised neutron stars

Dr Paul Scholz is a Dunlap postdoctoral fellow at the University of Toronto, Canada, and a member of the CHIME/FRB collaboration

How did you detect this FRB with CHIME?
CHIME (Canadian Hydrogen Intensity Mapping Experiment) is a telescope in British Columbia, Canada. On 20 April 2020, the magnetar SGR 1935+2154 was about 20° away from the meridian of CHIME, where it has most of its sensitivity, but we still detected a burst that appeared very bright and it lit up our telescope like a Christmas tree. And this is because it was closer than any other past FRB source.

Then the exercise began to determine where it came from. We saw it was coming from the location of a magnetar. We quickly wrote an Astronomer's Telegram [to post on a website where astronomers place short announcements needing a rapid response], and then the STARE2 team – the Survey for Transient Astronomical Radio Emission project in the western USA – immediately took a look at their own data and saw they'd also detected this event.

How might magnetars produce FRBs?
There are a few theories, but the basic picture is that you have a magnetar with an extremely large magnetic field and something happens either in the magnetosphere or on its crust – either a starquake or some of the magnetic field lines in the magnetosphere snap, and you get a large release of energy and charged particles flowing through the magnetosphere. And then somehow during that energy release you produce a bright flash of radio waves. Some models have it happening further out from the neutron star where you have some debris left over from previous flares and the charged particles ram into that and then create radio waves.

What are the wider implications of your study?
This event told us that yes, magnetars are capable of producing FRBs like those we see in other galaxies. While it suggests that possibly all FRBs, or maybe just a portion, are caused by magnetars, it definitely tells us that magnetars are a viable and likely source.

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THE SOUTHERN HEMISPHERE

With Glenn Dawes

Enjoy the distinctive star patterns of the southern Milky Way, including the Southern Cross

When to use this chart

1 April at 00:00 AEDT (13:00 UT)
15 April at 23:00 AEDT (12:00 UT)
30 April at 22:00 AEDT (11:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

APRIL HIGHLIGHTS

A supermoon sounds impressive but it's neither spectacular nor a rare event (happening three times in 2021). A loose definition would be when the Moon is full within approximately one day of being closest to Earth (perigee). On 27 April the rising full supermoon will be only 6 per cent larger and around 1.3 times brighter than when full at its average distance from Earth. The Moon illusion, an optical illusion where it looks bigger when close to the horizon, would make a bigger impression.

STARS AND CONSTELLATIONS

April is an ideal time to observe the southern Milky Way in the evening sky – just face south and look up. There are two key star patterns to help get your bearings – both crosses. The Southern Cross (Crux) is easily recognised with two bright pointer stars, Alpha (α) Centauri and Beta (β) Centauri, following behind (left). Westward (right) of Crux, about an open-hand span away, is the false cross, made up by borrowing two stars each from the constellations of Carina and Vela.

THE PLANETS

In April the evenings belong to Mars, which can be found in the northwest below Orion, departing around 21:00. Next up is Saturn, arriving in the early morning (rising 01:00 midmonth), followed by Jupiter an hour later. The gas giants spend the month in the constellation of Capricornus.

Neptune enters the predawn sky (rising 04:00 midmonth); this outermost planet opens April within a few degrees of the innermost planet. Mercury, however, fades from sight as it drops into solar conjunction.

DEEP-SKY OBJECTS

In the constellation of Centaurus, the Centaur, you'll find the naked-eye (mag. +3) star Lambda (λ) Centauri located on the northwestern edge of open star cluster IC 2944 (RA 11h 38.3m, dec. -63° 22'). IC 2944 features an alignment of around a dozen stars appearing to flow away from Lambda towards the southeast - all fitting in a 0.5° field. IC 2944 also has a nebula component, the visually challenging Running Chicken Nebula.

Move 1.5° north of Lambda to discover an impressive open cluster NGC 3766 (RA 11h 36.2m, dec. -61° 36'). Even binoculars show a distinctive hazy patch standing out in a rich Milky Way region. Telescopes show a compact (10 arcminute), fan-shaped array of mostly 9th to 11th magnitude white stars, hence, the Pearl Cluster. Enjoy the complex arrangement of interlocked curved lines of stars.

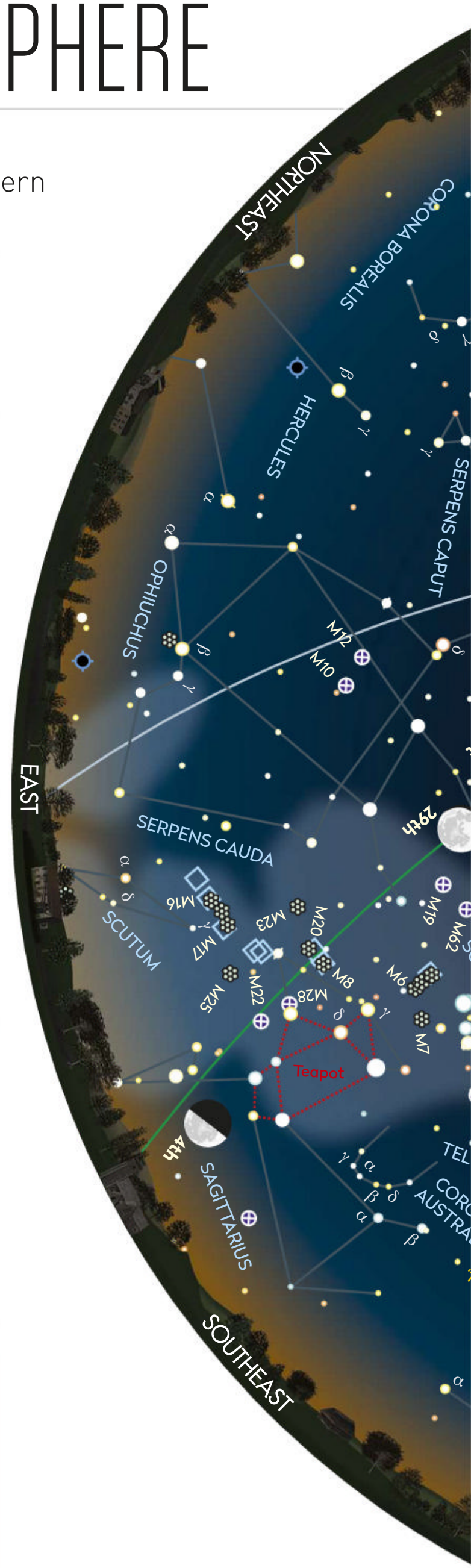

Chart key

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
URSA MAJOR
M51
M106
BOÖTES
Kite
CANES VENATICI
M63
M94
Cor Caroli
LYNX
LEO MINOR
COMA BERENICES
M3
Arcturus
M64
Denebola
LEO
Sickle
Regulus
20th
M44
23rd
Ecliptic
M86
M84
M87
M60
VIRGO
CANCER
CANIS MINOR
M5
26th
Spica
M104
CRATER
HYDRA
Alphard
Procyon
Celestial Equator
LIBRA
CORVUS
Ghost of Jupiter
M48
MONOCEROS
Winter Triangle
M830
CENTAURUS
Cen A
M4
Antares
LUPUS
ANTLIA
PYXIS
M93
M47
VELA
CRUX
NGC 3766
Hadar
Rigel Kent
Jewel Box
Coal Sack
Acrux
IC 2944
Sirius
M41
CANIS MAJOR
PUPPIS
CIRCINUS
NORMA
CORPIUS
MUSCA
False Cross
ARA
TRIANGULUM AUSTRALE
CHAMAELEON
CARINA
APUS
VOLANS
Canopus
COLUMBA
MENSA
South Celestial Pole
Tarantula Neb
LMC
PICTOR
PAVO
OCTANS
SMC
DORADO
47 Tuc
HYDRUS
RETICULUM
INDUS
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